Vol. XIII, Part V

October, 1943

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority of The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23*s*. 6*d*.

Price per part
Rs. 3 or 5*s*.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI,
1944.

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(October 1943)

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ORIGINAL ARTICLES

STUDIES IN THE PERIODIC PARTIAL FAILURES OF THE PUNJAB-AMERICAN COTTONS IN THE PUNJAB

VIII. THE RELATION OF WEATHER FACTORS WITH THE SPREAD OF *TIRAK* IN AMERICAN COTTONS*

By R. H. Dastur† and Uttam Chand Tashna, Punjab Agricultural College, Lyallpur

(Received for publication on 10 August 1942)

(With ten text-figures)

Partial failures of the Punjab-American cotton crop in the Punjab occurred in the year 1919, 1920, 1921, 1926, 1927, 1928, 1931 and 1932. During these years the American cottons suffered from a disease commonly known as *tirak* or bad opening. The condition of the crop was reported to be normal up till September in these years. Towards the end of September the symptoms of *tirak* appeared. These symptoms were, early reddening and shedding of leaves, cracking of the bolls, and the production of immature seeds with low quality of lint. The intensity of *tirak* varied from field to field and it was reported that the damage was more on poor soils than on good ones. In some fields the crop was quite normal while in others the opening was found to improve in the months of November and December.

The causes that gave rise to these partial failures of American cottons in the Punjab in certain years have been a subject of discussion for the last 15 years. Various views were expressed regarding the causes of such periodic occurrence. These views are briefly discussed below.

Milne [1920; 1922; 1928] expressed different views regarding the causes that gave rise to these failures. Amongst them two may be mentioned in the order they were expressed: (1) Inadequacy of water supply in the months of September and October which were dry and warm, and (2) the crop suffered from 'heat stroke' in the early stages of growth on account of high temperature and low humidities in May-June. A number of suggestions regarding the possible causes of this periodic occurrence have also been recorded by Milne [1928]. None of these statements or suggestions was, however, supported with experimental or any other kind of evidence.

Roberts [1929] and later Thomas [1930] attributed the failures of 1926, 1927 and 1928 to the prevalence of white-fly which damaged the cotton crop in these years. It was later demonstrated with certain amount of experimental data by Husain and Trehan [1932] that though white-fly lessened the boll production by damaging the leaves, this was not the cause of the widespread occurrence of *tirak* which was a general feature of the cotton crop in the failure years.

Trought [1931] attributed these failures to the operation of three kinds of factors, viz. climatic, biotic and physiological. He had also definitely ruled out the soil factors as playing any part in the development of *tirak* in these failure years. The part played by the soil conditions in the development of *tirak* in American cottons is already reported in the contributions by Dastur [1941] and by Dastur and Samant [1942] on the *tirak* problem and it is therefore now unnecessary to discuss the view expressed by Trought [1931].

The relation of weather conditions to *tirak* is now studied from the point of view of the fresh knowledge gained on the causes of *tirak*. The statistical methods developed by Fisher [1924] and others have been employed. The whole investigation is divided into two parts.

I. A statistical study of the trends in yields of the American and *desi* cottons in the Punjab for the period 1914-1940 and the relation of weather factors to the annual variations in yields.

II. A study of the weather factors that cause a greater spread of *tirak* in some years (failure years) than in others.

I. Investigation

Yields of cotton in the Punjab

As the partial failures of the American cottons occurred in all the important districts of the Punjab, it was thought necessary to determine the depressions in normal yields that occurred in these years in the whole province as well as in each of the important cotton-growing districts.

Such a study would reveal what were the bad, partially bad and good crop years and to what extent the yields were depressed or enhanced in bad or good years of the cotton crop in the Punjab,

* The work reported in this paper was done in the Punjab Physiological (Cotton Failure) Scheme financed jointly by the Indian Central Cotton Committee and the Punjab Government

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Taking the province as a whole it was found that the yields were reduced to 3·18, 3·28 and 3·14 maund per acre for the three failure years 1921, 1926 and 1928 respectively, the average of 15 years (1921-35) being 5·26 md. per acre (Table I).

TABLE I

Yields of seed cotton (Americans) in md. per acre in the eight districts and in the whole province (1921-35)

District	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Average of 15 years
1. Gujrat . . .	5·99	5·98	5·51	6·75	5·75	2·51	6·48	3·74	5·48	5·20	3·74	4·47	4·94	7·59	6·69	5·38
2. Gujranwala . .	3·50	3·69	3·52	3·81	4·51	2·03	5·47	3·49	5·04	4·55	3·63	4·94	4·25	6·69	6·58	4·38
3. Shahpur . .	3·00	5·00	6·00	5·84	3·99	2·00	6·00	2·75	3·00	3·94	3·75	3·75	5·97	8·19	7·06	4·62
4. Sheikhupura. .	3·50	4·98	6·99	7·78	5·49	3·50	5·00	3·50	5·48	5·24	4·49	5·00	6·45	7·72	8·37	5·57
5. Lyallpur . .	2·50	5·99	7·00	7·30	6·50	3·94	5·00	3·25	6·00	5·99	6·01	5·51	7·50	8·75	9·50	6·05
6. Montgomery .	3·00	5·01	7·00	5·84	5·00	3·24	4·01	3·00	6·51	6·50	5·25	5·00	10·01	7·25	9·00	5·77
7. Jhang . . .	2·50	4·51	6·00	4·85	3·99	3·98	3·99	2·74	3·99	4·99	3·98	3·50	6·25	5·98	6·47	4·51
8. Multan . .	3·00	4·23	4·99	5·34	4·00	3·50	3·01	2·75	4·00	4·50	4·00	4·01	7·00	8·25	7·50	4·67
Average of the eight districts	3·37	4·92	5·88	5·94	4·90	3·09	4·87	3·15	4·94	5·11	4·36	4·52	6·55	7·55	7·65	5·12
Average of the whole province	3·18	5·00	6·32	6·10	5·06	3·28	4·73	3·14	4·99	5·22	4·56	4·53	7·30	7·67	7·86	5·26

These years were reported to be the worst years for the American cottons in the Punjab. Similarly the yields were low in 1927, 1931 and 1932 fluctuating between 4·5 to 4·7 md. per acre. The yields were normal in 1922, 1925, 1929 and 1930 and very good in the remaining years. The average yields of the whole province were lowered by 39·5, 37·6 and 40·3 per cent of the general mean of 1921-35 in the year 1921, 1926 and 1928 and 10 to 13 per cent in 1927, 1931 and 1932.

When the yields of the different districts were separately studied, it was seen that in all the eight districts (with the exception of Gujrat in 1921) the yields were low in the three years 1921, 1926 and 1928. The extent to which the yields were lowered in each district during these years varied from district to district.

It has been previously stated that the *desi* cottons did not suffer in yields to a great extent in these failure years and the term 'failure' was applied to low yields of the American cottons which exhibited the symptoms of *tirak*. The yields of the *desi* cottons were therefore studied to see if there were similar depressions in their yields during the same years (Table II). Taking the province as a whole, the yields of the *desi* cottons had fluctuated from 2·89 to 5·57 md. per acre during the 15 years, the general mean yield for the same period being 4·05 md. per acre. Thus the yields of *desi* were, on the whole, lower by nearly 1·21 md. than the yields of Americans. The results showed that the yields of the *desi* and the American crops were good, normal or bad in the same years, the yields of both the Americans and the *desis* were very low in 1926 and 1928, good in 1924, 1933, 1934 and 1935 and normal in 1925, 1929 and 1930. In 1931 the *desis* suffered more than the Americans and in 1921 and 1927 the Americans suffered more than the *desis*. The general conclusion is that in most of the years the *desi* and the American crops have been equally good, normal or bad. Thus the only difference between the failures of the American and the *desi* cottons was that the *desi* plants did not exhibit the external symptoms of *tirak*, viz. the early reddening and shedding of the leaves and the bad opening of the bolls. This is a very important point to be considered. The yields of seed cotton may be lowered when *tirak* occurs, but the yields of seed cotton may also be lowered if the number of bolls per plant is reduced. It is possible that the *desi* plants are physiologically different from the American plants and therefore such symptoms of *tirak* do not develop in the former.

The foregoing yield data relating to the American and *desi* cottons during the 15 years were statistically analysed to see how far the general conclusions reached above were supported.

The correlational analysis of the yields of the American and *desi* cottons showed that there was a highly significant correlation between the *desi* and the American yields in all the eight important districts, the values of correlation coefficients ranging from 0·7248 to 0·9147 ($n = 13$). This supports the general conclusion that the *desi* cottons did badly or well in the years in which the American cottons failed or gave high yields.

The successive year correlation in the case of both *desi* and American cottons came out to be

significant in the case of one district (Multan) while suggestive in the case of a few others. The pooled correlation coefficients for both were found to be highly significant, $r = 0.3285$ for *desi* and 0·4026 for Americans. Thus there is a tendency for low-yielding and high-yielding years to be associated together in groups—1919, 1920 and 1921; 1926, 1927 and 1928; and 1931 and 1932 were low-yielding years, while 1923 and 1924; and 1933, 1934 and 1935 were high-yielding years. The yields of American and the *desi* cottons have gone up during the last few years, and this conspicuous increase in the yields since 1933 has in all cases considerably increased the regression of yield on time.

TABLE II

Yields of seed cotton (desi) *in md. per acre in the eight districts and in the whole province (1921-35)*

District	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Average
1. Gujrat . . .	3·38	4·50	3·77	3·56	3·88	2·46	3·79	3·00	4·52	4·36	2·68	3·51	4·87	6·11	4·55	3·93
2. Gujranwala . .	3·43	2·97	2·51	3·72	3·41	2·14	4·27	2·55	3·84	3·84	1·93	4·01	4·48	4·43	4·90	3·50
3. Shahpur . .	2·98	3·83	4·46	3·16	2·84	2·33	4·17	2·33	3·40	4·12	2·12	2·97	4·58	6·34	4·81	3·63
4. Sheikhupura .	3·43	2·56	4·29	5·79	4·24	2·97	4·30	2·78	5·15	3·85	2·55	3·62	5·70	6·54	6·18	4·26
5. Lyallpur . .	3·00	3·43	5·25	6·25	5·15	4·35	3·42	3·00	5·36	4·28	3·43	4·29	7·72	6·22	7·07	4·81
6. Montgomery .	3·45	5·15	6·00	4·98	4·28	3·00	3·43	2·14	5·15	5·14	2·79	4·07	6·88	5·79	6·86	4·60
7. Jhang . . .	3·00	2·56	4·23	4·18	3·81	4·11	3·35	2·12	2·81	3·52	2·67	2·47	5·27	4·26	4·61	3·53
8. Multan . .	3·42	3·43	3·85	3·74	3·22	3·00	2·58	2·13	3·00	3·42	2·14	2·99	4·71	5·35	4·69	3·44
Average of eight districts	3·26	3·55	4·28	4·42	3·85	3·05	3·66	2·51	4·15	4·07	2·54	3·49	5·52	5·63	5·46	3·96
Average of whole province	3·63	3·75	4·05	4·41	3·86	2·89	3·75	3·03	4·48	4·16	3·22	4·22	4·77	5·06	5·57	4·05

As there was an indication of an upward trend in yields of the American and *desi* cottons, it was necessary to eliminate before studying the relation of yields in relation to weather factors, these progressive changes in yields caused either by introduction of improved varieties or by adoption of improved methods of cultivation.

The yields given in Tables I and II were calculated from the averages and the bales of cotton given in the *Season and Crop Reports* published by the Director of Land Records. Prior to 1921 the averages and bales of cotton were not given separately for Americans and *desis*. The data given in these reports cannot be considered ideal for a statistical study. There are various defects in this data. The bales of cotton marked as Americans may contain proportion of *desi* lint mixed with it. The mixture of *desi* and American cotton in a bale varies to a very wide extent. The figures given for the bales of cotton separately for each district may not be correct as the seed cotton for ginning and pressing may go from one district to another. As it was, however, not possible to obtain more reliable data than those given in these reports, they were taken for this study.

The yield data of 20 years (1921-40) for the eight different American cotton-growing districts were analysed by the analysis of variance in order to determine whether there was any variation in the yield estimates from district to district (between districts) and from year to year (between years).

	D. F.	M. square	F.
Between districts . .	7	6·925	8·260**
Between years. . .	19	20·538	24·497**
Within years . . .	133	0·8384	

The variation between districts was found to be significant, indicating that the nature of yield estimate from district to district was very variable. The variation between years was also significant indicating the effect of seasonal conditions in the yearly estimates. The annual variations in yield were thus found to occur.

For the purposes of further studies, three important cotton-growing districts, viz. Lyallpur, Montgomery and Multan, were selected. As the conditions of cultivation would vary greatly within a district, the yields of three commercial farms, one from each of the three districts, were also collected as the conditions of cultivation in a farm were assumed to remain fairly uniform. The yield figures were kindly supplied by the authorities of three farms (1) Brucepur Farm, Lyallpur, (2) Military Farm, Okara, and (3) The B. C. G. A. Farm, Khanewal, and they are given in Table III.

TABLE III

The yields of seed cotton (Americans) in md. per acre at different cotton farms in the Punjab (1921-40)

Year	Col. Bruce's Farm, Brucepur	Military Farm, Okara	B. C. G. A. Farm, Khanewal
1921	6·30	2·89	7·81
1922	5·20	8·63	11·12
1923	4·15	6·37	14·23
1924	5·30	4·83	15·45
1925	8·80	8·62	15·13
1926	6·35	3·08	7·28
1927	5·20	5·90	4·58
1928	5·40	4·40	5·65
1929	7·81	7·76	10·15
1930	6·62	7·55	11·70
1931	6·11	8·12	10·03
1932	7·47	7·59	8·27
1933	7·76	11·53	12·48
1934	10·10	8·09	10·83
1935	13·60	8·44	8·33
1936	12·76	10·08	12·78
1937	11·29	7·88	8·26
1938	9·66	7·60	7·67
1939	8·28	4·82	3·63
1940	10·61	7·35	14·17

The similar trends in the mean values of yields for the three districts, the three commercial farms and for the Punjab were first studied by employing Fishers' method of 'polynomial curves'. The total sum of squares of deviations were split up by the analyses of variance into three parts (*a*) the sum of squares for the average rate of change with one degree of freedom, (*b*) the sum of squares for secular trends, and (*c*) the sum of squares due to the annual fluctuations assigned to weather conditions.

The analysis of variance for the yields of Americans for 1921-40 and for the Americans and *desis* together for the 27 years period (1914-40) for the three districts and for the Punjab are given in Table IV. Prior to 1921 separate figures for bales for Americans and *desis* are not given in the *Season and Crop Reports*.

There was a definite indication that the cotton yields in the Punjab as well as in the districts had materially changed during these periods as is shown by the significant nature of the average rate of change. The same had been the case with the yields of the two farms located in the Lyallpur and the Montgomery districts but the B. C. G. A. Farm formed an exception to this rule (Table V). Although the changes in the mean yield are predominantly linear in trend the nature of slow changes other than linear is also significant.

TABLE IV

Analysis of variance

Due to	American (1921-40) D. F.	American (1921-40) Mean square	American and *desi* (1914-40) D. F.	American and *desi* (1914-40) Mean square
Province				
Average rate of change . .	1	21·0571		
Secular changes . .	4	4·4316		
Residual	14	0·890		
Lyallpur				
Average rate of change . .	1	32·5687	1	32·4797
Secular changes . . .	4	7·6669	3	2·4305
Residual	14	0·8233	22	1·7390
Montgomery				
Average rate of change . .	1	18·8469	1	22·5910
Secular changes . . .	4	8·4001	3	3·9824
Residual	14	1·5134	22	1·5544
Multan				
Average rate of change . .	1	38·0924	1	33·1431
Secular changes . . .	4	6·0945	3	4·8484
Residual	14	0·7683	22	1·0141

TABLE V

Yield in md. per acre of Americans

Due to	D. F.	Brucepur Mean square	Military Farm Mean square	B. C. G. A. Mean square
Average rate of change .	1	75·5005	13·9712	7·8159
Secular trends . .	4	4·4403	8·6154	29·5041
Residual . . .	14	3·0155	3·1159	7·1073

The secular variations in mean yields of Americans for the three districts and the three farms can be studied from Table VI.

The coefficient of variability was of the same order in the districts as well as at the three commercial farms. Multan district gave the highest coefficient of variability. Though the nature of slow changes was supposed to be purely a local feature, the similarity in the three districts was evident from the significant positive nature of X′2 and X′6 and the significant negative nature of X′5 in the American yields. Similar trends in the yields of the Province were also noticed. The coefficient of variability was found to be of the same order in the three districts when the yields of Americans and *desis* were taken together for a period of 27 years (Table VII).

TABLE VI

Yields of Americans in md. per annum 1921-40

	Lyallpur	Montgo-mery	Multan	Brucepur	Military Farm	B.C.G.A. Farm	Punjab
Mean	6·63	5·60	5·33	7·94	7·08	9·98	5·74
S. D.	1·98	1·97	1·97	2·67	2·20	3·44	1·64
C. V.	30·0	32·8	36·9	33·6	31·1	34·5	28·60
X′2	+5·71	+4·34	+6·17	+8·69	+3·74	—2·80	+4·59
X′3	+0·62	—1·46	+1·49	+0·47	—2·87	+1·19	+0·83
X′4	—1·24	—3·49	—2·15	—3·38	—2·98	+0·73	—1·69
X′5	—3·55	—2·66	—2·08	—2·42	—1·04	—1·93	—2·64
X′6	+4·02	+3·50	+3·66	..	+4·03	+10·60	+2·69
S. R.	0·91	1·23	0·87	1·68	1·77	2·67	0·94
Years	20	20	20	20	20	20	20

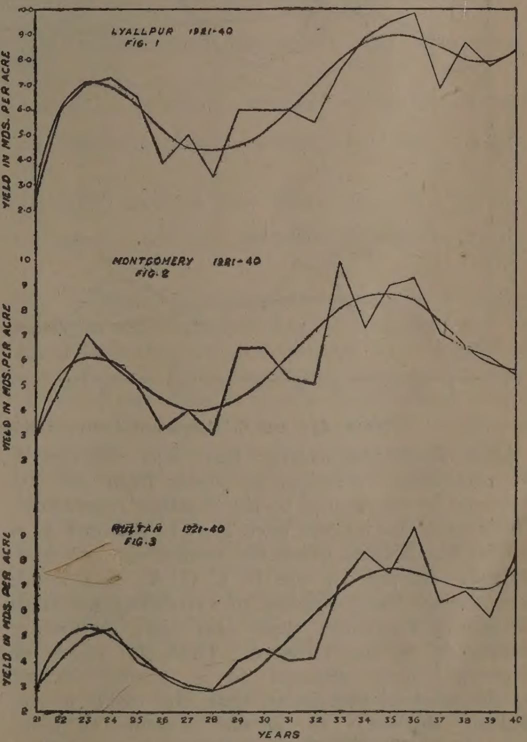
TABLE VII

Yields of Americans and desis *in md. per annum*

	Lyallpur	*Montgo-mery*	*Multan*
Mean	5·42	5·02	4·44
S. D.	1·73	1·61	1·64
C. V.	31·9	32·5	36·9
X′2	+5·70	+4·75	+5·76
X′3	+1·23	—0·02	+2·57
X′4	+0·18	—1·20	+0·76
X′5	—2·39	—3·24	—2·71
S. R.	1·32	1·25	1·01
Years	27	27	27

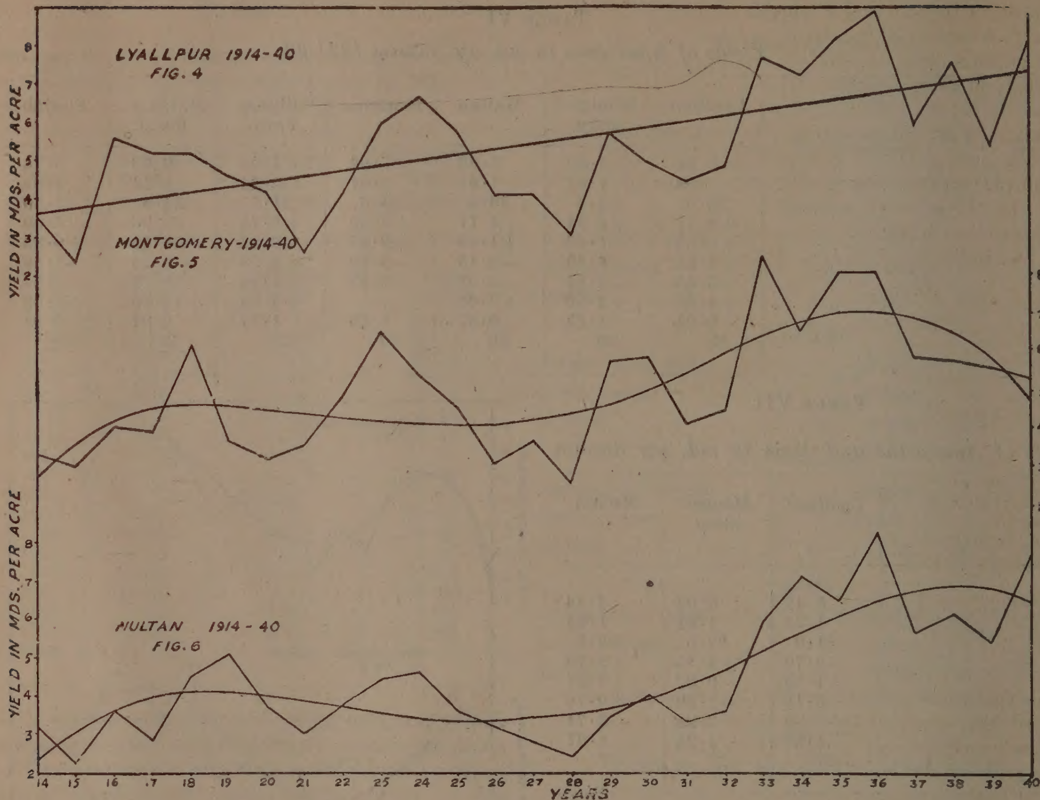
The curves indicating the slow changes are shown in Figs. 1, 2 and 3 by polynomial curves of the fifth degree for American yields for the three districts. In this case it may be remarked that the fifth degree curve on the whole gives a better fit than the linear or the cubic regressions. When the yields of Americans and *desis* combined together were considered the slow changes were best expressed by the linear regression. X′5 was negative and was significant in the case of Montgomery and Multan but it was not significant in the case of Lyallpur even though it was higher than the standard residue. Thus a straight line was fitted to the Lyallpur data (Fig. 4) and fifth degree curves to other districts (Figs. 5 and 6).

Amongst the commercial farms the Brucepur and the Okara Farms showed the slow changes which could be best expressed as linear though the values for X′4 and X′5 were negative and much higher than the standard residue. The yields at Khanewal Farm were found to be highly variable and did not show any slow changes on the whole. The first four transformed coordinates did not therefore reveal any secular trends while he value for the fifth degree was very high.



FIGS. 1, 2 and 3. Polynomial curves fitted to the yields of American cottons

The secular changes in yields in such large areas as districts cannot be regarded as localized effects. One of the most important reasons for the upward trend in yields might be the introduction of high-yielding varieties of cotton. This was really so in the case of the Brucepur Farm where 4F variety was replaced by the L. S. S. from 1933. The same can be said of Khanewal where 4F was replaced by 289F and later by 289F/K25. At Military Farm, Okara, the acreage under Americans was increased from 1936 onwards.



Figs. 4, 5 and 6. Polynomial curves fitted to the yields of American and *desi* cottons

After the secular changes have been eliminated the remaining variations in yields from year to year can be attributed to the weather conditions. The annual variations were greatly reduced in a district like Multan where the secular changes were highest. In case of the B. C. G. A., Khanewal, even though the coefficient of variability was high the annual variations were also high, indicating absence of secular changes. Thus the yields at Khanewal were affected to a greater extent by the weather conditions than the yields in the Multan district. It is not possible to compare the annual variations in the three districts with one another for the simple reason that the climatic complex would not be the same in the three districts. The value of standard residue in the case of the three districts or the three farms would, therefore, indicate only the reduction in the variations of yield series after the elimination of the secular changes. In Lyallpur there was a reduction in the total variation of 79 per cent on account of the secular changes.

From what has been stated above it was necessary to eliminate secular variations from the yield series in order to study the correlation of weather factors with the variations in the yields of cotton.

Effect of joint climate

A general study of weather conditions at Lyallpur for each year of the period 1921-35 was undertaken in order to determine if there were any abnormalities of weather that could be correlated with the years of low yield. The weekly and monthly means of maximum and minimum temperatures, the weekly range of temperature (maximum—minimum) and the weekly means of humidities for the months of May to October at Lyallpur were studied for good, normal, partially bad and bad yield years. The results of such a study were complex and no indication of the nature of weather complex that could be regarded as a feature of either a good or a bad crop year was obtained.

In the same way, when the rainfall figures (month by month for the remaining districts) were studied, no indications were obtained regarding the direct relationship of rainfall either with the failure years or with the good crop years.

In order to study the correlationships between yields and weather factors the year is divided into four periods, viz. January-April, May-June, July-August, and September-October in order to determine the influence of weather conditions on the crop yields for the pre-sowing period and for three periods during the cotton season.

Simple correlation coefficients between yields and the three weather factors, i.e. rainfall, temperature and humidity were determined for Lyallpur without and after eliminating the secular changes of the required degree. The secular changes in temperature and humidity were also found to occur and were eliminated. Correlation coefficients between yields and the three weather factors for all periods were non-significant except in two cases. Humidity for the period May-June came out to be positively correlated with the yields and the correlation coefficient between average temperatures $\frac{M+m}{2}$ for the same months and yields was on the verge of significance and negative (Table VIII).

TABLE VIII

Correlation coefficients between yields and weather factors (Lyallpur 1921-35)

Period	A Without eliminating secular changes				B After eliminating secular changes			
	Jan.-April	May-June	July-August	Sept.-Oct.	Jan.-April	May-June	July-August	Sept.-Oct.
Average range of temperature	—0·4998	—0·0541	+0·1085	+0·1821	—0·1634	—0·1286	—0·0476	—0·1707
Mean of maximum and minimum temp. $\frac{M+m}{2}$	—0·5227	—0·5386	—0·1495	—0·1550	—0·2378	—0·5286	—0·1508	—0·0839
Average humidity .	+0·5446	+0·1475	+0·1724	—0·3328	+0·1996	+0·7241*	+0·4123	+0·2750
Total rainfall .	+0·5403	+0·1759	—0·0925	—0·4235	+0·3007	+0·3565	+0·3292	—0·4601

As the values of correlation coefficients for the period May-June (early part of the season) between humidity and yields and average temperature and yields were high, it was necessary to study their combined effect. This was done by fitting a regression equation and finding out partial regression coefficients. They were found to be non-significant (Table IX).

TABLE IX

Partial regression coefficients with standard errors for Lyallpur

Weather factors	Partial regression coefficients	S. E.
Mean of max. and min. temperature $(\frac{M+m}{2})$	—0·3917	±0·3297
Humidity	+0·1857	±0·1246
Rainfall	+0·0204	±0·7008

The preliminary investigation concerning the interrelationship of yield and weather factors was reinvestigated by considering the data for Americans up till 1940 and for the combined *desis* and Americans for 1914-40.

The correlation coefficients between maximum temperature for each fortnight from 1 August to 31 October and yields of American cotton (1921-40) are given in Table X for the three farms and for the three districts separately. The results are complex. Isolated cases of significant relationship between maximum temperatures of a fortnightly period between August and October are found and they do not permit any conclusion to be drawn. Thus maximum temperatures and yields of any district or any farm cannot be said to be correlated. Similar conclusion applies to correlation coefficients between maximum temperatures and yields of American and *desi* cottons for the period 1914-40.

The correlation coefficients for monthly rainfall and yields of Americans are given in Table XI and for the rainfall periods—July-August, August-September and September-October—are given in Table XII for the three districts and the three farms. The results are negative and provide no information.

It is not surprising to find that the annual variations in yields cannot be correlated with any single weather factor or to a combination of more than one factor. The reason for the inconclusive results of this study will be clear later. The main problem is to determine why *tirak* or bad opening of bolls in the American cottons occurred to a greater extent in some years than in other years. It is therefore necessary to investigate the problem from the point of view of *tirak* rather than the yields as the fluctuations in yields may be caused by a number of factors which may not have any effect on the spread of *tirak*. *Tirak* is only one of the several factors that lower the yields.

TABLE X

(Time trend eliminated)

Correlation coefficients between maximum temperature and American cotton yields

	1st half of August	2nd half of August	1st half of Sept.	2nd half of Sept.	1st half of Oct.	2nd half of Oct.
1921-40 (n=14, r=0·4973 at 5 per cent level, r=0·6226 at 1 per cent level)						
Lyallpur	+0·0605	—0·7682**	+0·1327	—0·0992	+0·1911	—0·0310
Montgomery	—0·2989	—0·4492	—0·2836	—0·1707	—0·2031	—0·0456
Multan	—0·1389	—0·3246	—0·4187	—0·4572	—0·0653	+0·3493
Brucepur Farm	—0·4077	—0·1511	+0·5891*	—0·1417	—0·0228	—0·8899**
Military Farm, Okara	—0·4980*	—0·3139	—0·1144	—0·1761	—0·4482	—0·3356
B. C. G. A. Farm, Khanewal	—0·2342	—0·3495	—0·3726	—0·2557	+0·1667	—0·3274
1914-40 (n=25, r=0·3809 at 5 per cent level; n=22, r=0·4061 at 5 per cent level)						
Lyallpur	—0·1420	—0·3258	—0·1083	—0·3876*	—0·2270	—0·0391
Montgomery	—0·2337	—0·4064*	—0·0120	—0·2813	—0·3342	—0·0267
Multan	+0·0867	—0·2736	—0·2195	—0·2240	—0·2198	+0·0165

TABLE XI

	July	August	September	October
Lyallpur	+0·1947	—0·2118	—0·1835	—0·0615
Montgomery	+0·2404	+0·0716	—0·2660	—0·0301
Multan	+0·4105	+0·2063	+0·3817	+0·2367
Brucepur Farm	+0·2550	—0·3624	—0·1899	+0·5294*
Military Farm, Okara	—0·1193	+0·1709	+0·0546	+0·0116
B. C. G. A. Farm, Khanewal	+0·8888	+0·2798	+0·2176	+0·2301

TABLE XII

	July-August	August-Sept.	September-October
Lyallpur	—0·0211	—0·2609	+0·6391**
Montgomery	+0·3567	—0·1144	—0·2670
Multan	+0·4324	+0·4329	+0·2895
Brucepur Farm	—0·1390	—0·4180	—0·0609
Military Farm, Okara	—0·0816	—0·1127	+0·1117
B. C. G. A., Khanewal	+0·4232	+0·3009	+0·0756

The problem of the annual fluctuations in cotton yields is more complicated in the Punjab than in any other cotton-growing province or country on account of the prevalence of this physiological disease. In the Punjab in addition to the variations in the boll numbers that may occur on account of the operation of some kinds of environmental factors, this physiological disease of *tirak* affects the size of the boll, i.e. weight of *kapas* per boll. The variation in the boll weight in the American cottons is of a great magnitude. The normal weight of seed cotton per boll in American cottons is about 2 gm. but it may be reduced to 0·3 gm. when *tirak* occurs. At the same time *tirak* does not reduce the number of bolls. No such reduction in the boll size is found to occur in *desi* cottons in the Punjab where the weight of seed cotton per boll fluctuates within a narrow range of 1·4 to 1·8 gm. The annual fluctuations in yields in the American cottons may thus be determined both by boll number and the boll weight and these two morphological characters of the plant may be adversely affected by different environmental factors. Those factors which may decrease the boll number may have no effect on the boll weight and vice versa. Similarly the factors which increase or decrease the boll production may operate at different stages of growth from those that increase or decrease the boll weight. Thus no direct relationship between weather factors and yields, which are the products of boll numbers and boll weight, is expected. It is therefore necessary to determine the weather factors that affect the boll weight, i.e. that affect the development of *tirak* in the American cottons in the Punjab in order to understand the 'failure years'.

II. WEATHER FACTORS AND SPREAD OF *TIRAK*

Immaturity of seeds is the chief symptom of *tirak*. It is now known to be caused by two different soil factors. It is either caused by a deficiency of nitrogen or by the presence of salinity in the subsoil. The development of *tirak* on account of two different soil conditions

introduces further complications in the study as the spread of *tirak* on the two types of soil may be governed by different weather conditions. It is also found that the two soil conditions, salinity or alkalinity in the subsoil and nitrogen deficiency occur together. It is, therefore, necessary to study the development and spread of *tirak* on each type of soil. Quantitative determinations of intensity of *tirak* in the same field from year to year were also necessary to determine the nature of weather factors that increased or decreased the incidence of the 'disease'. Thus a study of the weather factors that affects *tirak* became possible only after the soil conditions that produced *tirak* in American cottons were known. In the absence of such precise knowledge of the main causes of *tirak* it was not possible to obtain any definite information on the subject.

The cotton crop in the Punjab has been under the observations of the senior author from the year 1935. The years 1935 and 1936 were very good for the cotton crops in the Punjab. In 1936 the average yield of seed cotton per acre for the whole province was nearly 8·9 md. as compared with the general average of 5·74 md. for the period 1921-40. Even in these years *tirak* was found to occur in some of the fields. The same fields were under observations during the succeeding years. It was then observed that *tirak* again occurred in the same fields when cotton was again grown.

The cotton crop was found to suffer from *tirak* in parts of the field where the soils were highly saline or alkaline in the subsoil. In the same field normal crops were also found to occur in patches and the investigations of the soil conditions under normal patches showed the absence of salinity in the subsoil. Wherever the subsoil contained medium or low salinity the crop was normal. Similar observations of the crop conditions in relation to salinity were made in a number of fields.

In the year 1939, which ultimately proved a partial failure year, the crops in such fields with irregularly distributed areas of high, medium or low salinity were normal up till September. Towards the end of September the appearance of the crop in each field altered. The leaves showed marked drooping. The condition of the crop became gradually worse in the month of October and *tirak* developed in a much more intense form than what was the case in the previous years. *Tirak* had also spread to regions of the fields where normal crops were noticed in the previous seasons. The plants showed definite signs of gradual desiccation. The bolls ceased to grow and opened prematurely. Generally 52 days is the normal period for the bolls to open after they are set while in such fields the bolls of 28 to 35 days old cracked on account of the slow desiccation.

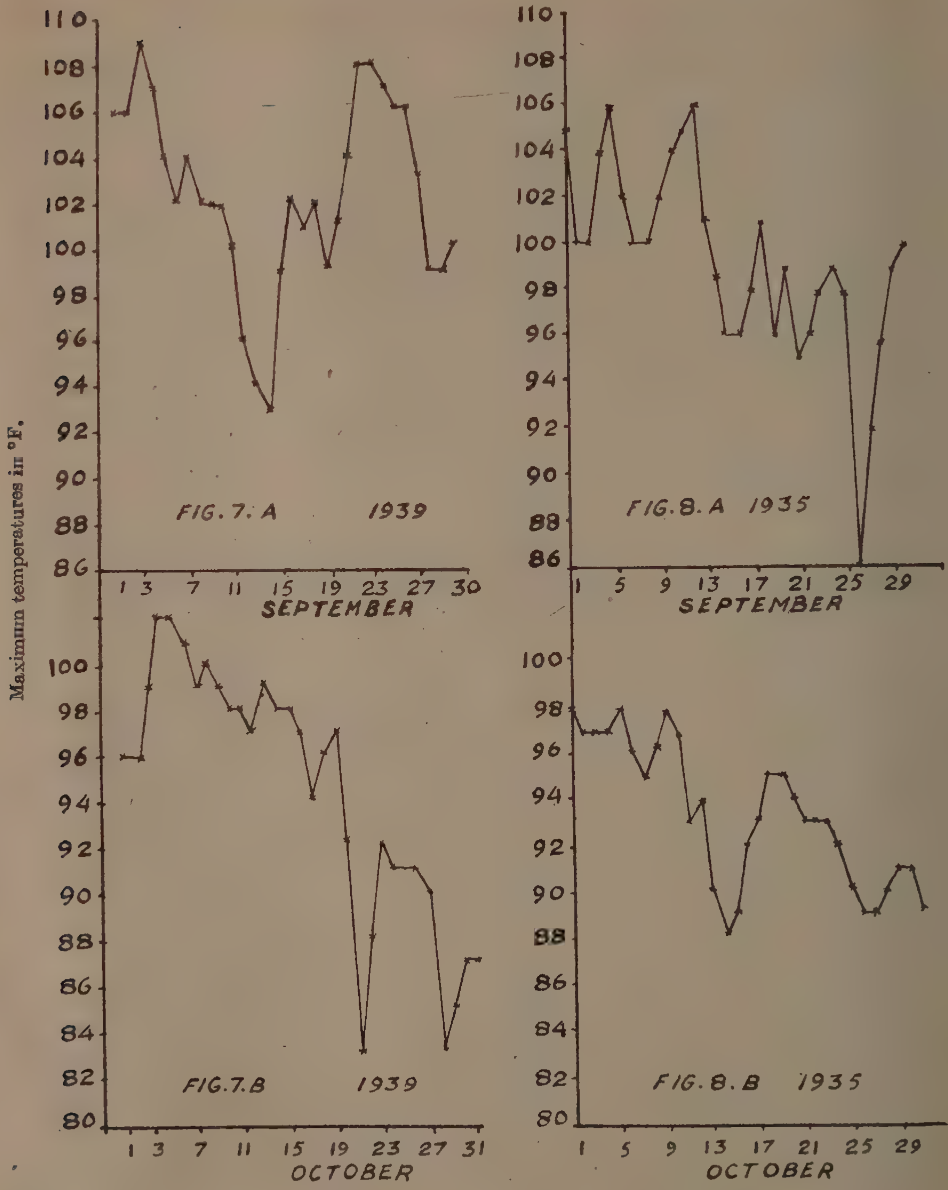
The crop indicated definite signs of a disturbance in its water supply. Such disturbance apparently occurred every year where the subsoil contained high salinity in the subsoil but in 1939 it was found that crop that came on patches of soils with medium and low salinity in the subsoil also suffered from a disturbance in their water supply after the plants had made normal growth. Consequently *tirak* also developed in such areas. The intensity of *tirak* had increased and it appeared on larger areas than normal.

It was clear that weather factors during the fruiting stage (September-October) that increased the water loss from the crop and produced a disturbance in its water balance were responsible for the spread of *tirak* on soils with medium and low salinity.

The months of September and October in 1939 were dry and warm. They were characterized by two long spells of very warm weather when the maximum temperatures were higher than normal. (Fig. 7 A and B). These months were also marked by the total absence of rain. The weather factors were therefore responsible for the incidence of *tirak* on soils with medium or low salinity. Under favourable weather conditions the crop is able to meet its water requirements even in presence of medium or low salinity in the subsoil and the crop does not suffer from *tirak*. But development of *tirak* occurs on such lands when the weather conditions produced a partial physical drought in addition to a partial physiological drought to which the crop is subject under saline conditions of the subsoil. On normal soils the adverse weather conditions at the fruiting stage do not disturb the water balance of the crop to such an extent as to produce *tirak* symptoms.

When the soils are highly saline in the subsoil the crop is exposed to a physiological drought as the absorption of water is rendered difficult by the presence of high concentrations of salt. *Tirak* symptoms in such cases develop in all years. *Tirak* is aggravated when the weather conditions are dry and warm. When the soils are of medium or low salinity *tirak* does not normally occur but if the months of September and October are warm and dry, *tirak* appears on such soils. If the soils are light and sandy with salinity and alkalinity in the subsoil *tirak* appears in the most intense form in such years.

Such widespread occurrence of *tirak* was noticed all over the Punjab in 1939. The crop was normal or *tirak* even in the adjoining fields depending on the absence or presence of salinity. When the temperature became low in November, the bolls



FIGS. 7 and 8. Maximum temperatures during September and October in bad and good crop years

that opened later in that month were normal. Thus all the observations recorded in the past on the conditions of the crop in the failure years of 1921, 1926, 1927 and 1928 were found to agree with those made in the year 1939.

The spread of *tirak* considerably lowered the yields. An idea of the extent to which the yield of seed cotton in a field with salinity in the subsoil is lowered when the weather conditions are abnormally warm and dry can be obtained from the yields and boll size determined for the crop in the same field for four years (Table XIII).

The yield per acre in Field I (Table XIII) was reduced to 4·78 md. from an average of nearly 14 md. per annum. Similarly the weight of the seed cotton per boll was reduced to 0·77 gm. Thus in 1939 *tirak* occurred in a very intense form and was more extensive than in previous years when *tirak* was only confined to a few patches which had subsoil with high salinity.

TABLE XIII

Year	Field I					Field II		
	1936	1938	1939	1940	1941	1937	1939	1940
Yields in md. per annum	14·50	15·48	*4·78*	13·53	18·16	16·00	*10·09*	17·7
Weight of seed cotton per boll in gm.	..	1·88	*0·77*	1·70	..	1·98	*1·15*	2·01

Thus direct observations of the crop in fields with saline subsoils gave the indication of the weather factors that increased the intensity and spread of *tirak*. It may be mentioned that the crop on soils with a deficiency of nitrogen did not show such intensification of *tirak* symptoms, while *tirak* occurred in an intense form on soils which were deficient in nitrogen and which had also saline or alkaline subsoil.

The soils in the Punjab are extremely heterogeneous. The soils with normal or saline subsoils are found intermixed. Such different soil conditions are found to occur in small areas. Similarly the normal soils and nitrogen deficient soils are also intermingled. In order to make observations on the variations in the intensity and spread of *tirak* it is therefore necessary to know the soil conditions on which the crop is growing.

In 1939 the months of September and October were marked by hot spells of warm and dry weather. The maximum temperatures were above normal during these spells. The first spell ocurred at Lyallpur from 12 to 27 September (Fig. 7A) and the second spell occurred from 4 to 16 October (Fig. 7B). The temperatures were also above normal from 4 to 12 November. In addition, the month of September was dry without any rain. Similar spells of hot weather occurred in the Multan and Montgomery districts.

For the sake of comparison the temperatures in the months of September and October for the good crop year of 1935 are given in Figs. 8A and 8B. The month of September was not marked with such spells of hot weather. The temperatures were below normal in the second fortnight of September. Similarly the month of October was not warm. It was already reported that *tirak* had not occurred in an intense form in 1935.

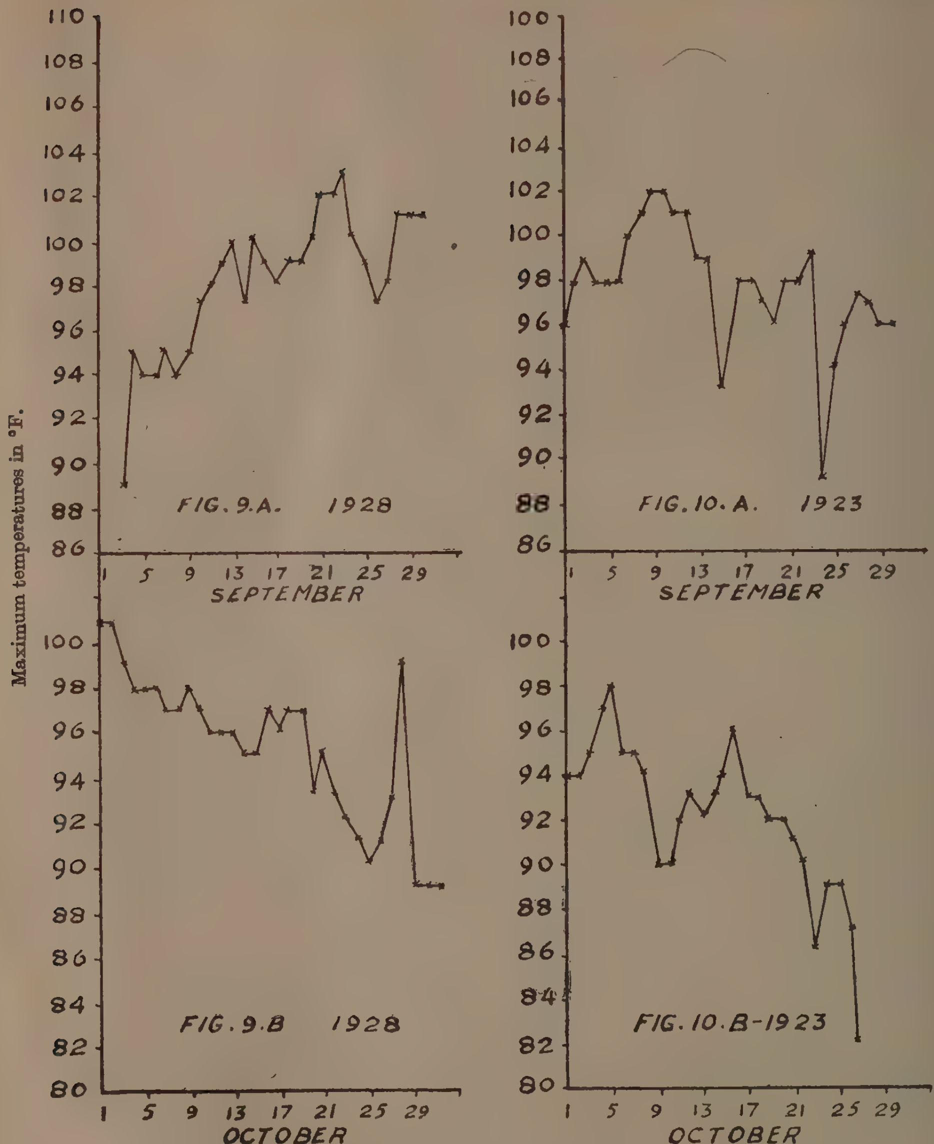
It may be asked whether similar warm spells of hot and dry weather at the fruiting stage were features of cotton failure years in the past when widespread occurrence of *tirak* occurred. 1923 was a very good crop year for the Punjab and 1928 was a cotton failure year when *tirak* had occurred. The maximum temperatures in the months of September and October are given in Figs. 9A and 9B for 1928 and in Figs. 10A and 10B for 1923. It will be seen that the temperatures in these months in 1923 were low without any long spells of hot weather while the temperatures during the same months of 1928 were high. The spell of hot weather in 1928 started from 12 September and ended on 19 October.

It is evident that the hot spells may occur at any time during these two months. The periods of hot weather may not coincide in two *tirak* years. The monthly mean of maximum temperatures may or may not come out above normal if the spell of hot weather occurs in the end of September and the beginning of October or the temperatures are unusually low for some days. This introduces difficulties in the statistical study of weather factors in relation to *tirak*, as the time, duration and the number of spells of hot weather may vary from year to year.

In order to get some quantitative idea of the severity of weather conditions in these two months in the *tirak* years the following data were calculated. The monthly means of maximum temperatures for the two months were calculated for good years and *tirak* years. The departures of these monthly means from the normal monthly mean as given in the weather reports were then calculated. The number of days for which the maximum temperatures were above the normal in these two months were also determined.

The rainfall figures for the months of July, August and September were calculated. Although the temperature figures were taken from the records at the headquarters, the mean district rainfall data for a district was obtained by averaging out the data of all the raingauge stations in the district (4 in Montgomery, 9 in Lyallpur and 6 in Multan). For the sake of comparison that the temperatures in September and October are important for the spread of *tirak*, similar determinations were also made for the months of July and August. These determinations were made for three districts: Lyallpur, Montgomery and Multan.

The years are divided into two groups (1) very good years of cotton crop indicating low incidence of *tirak* and (2) years indicating medium to high incidence of *tirak*. The medium *tirak* years may



Figs. 9 and 10. Maximum temperatures during bad and good crop years

be the years of normal yields. The years of medium *tirak* are shown by asterisks (Table XIV). The yields of the districts are not given for these years as the yields depend on other factors besides the intensity of *tirak*. As there is also an upward trend in the yields of cotton from the year 1933 it is not also correct to compare the yields of *tirak* before 1933 with those of the years after 1933. The object of this investigation is only to determine the probable weather factors that increase the incidence and the spread of *tirak*.

A study of the departures of the temperatures from the normal will reveal that in all good crop years the temperatures in the months of September and October are below the normal mean or one degree above normal in October. *Tirak* years, with some exceptions, are characterized by temperatures higher than the normal either in the month of September or October or both. In some *tirak* years the high temperatures are accompanied by very little rain or absence of rain in the months of August and Septembe- There are, however,

Table XIV

Lyallpur

	Departures from normal monthly means of max. temp.				No. of days when max. temp. were above normal monthly means				Rainfall in inches		
	July	August	September	October	July	August	September	October	July	August	September
Good years											
1923 . .	—0·3	—3·6	—0·3	—2·6	14	10	18	14	2·64	6·54	0·40
1924 . .	+2·5	+1·4	—3·5	+0·4	20	22	3	14	2·70	1·36	3·36
1933 . .	—1·9	—5·8	—3·5	+0·6	14	4	7	13	1·6	7·55	1·81
1935 . .	—0·8	—0·1	+1·5	+1·9	12	14	18	*22*	3·24	2·32	0·30
1936 . .	—2·8	+2·2	+1·9	+0·6	10	21	22	19	3·01	1·09	0·87
Tirak *years (Asterisks indicate medium* tirak *years)*											
1926 . .	+0·9	—2·3	—2·3	+0·8	18	9	10	*16*	3·21	4·33	1·73
1927* .	—2·2	+1·2	*+2·1*	*+1·6*	12	16	*26*	*24*	2·21	0·48	*0·75*
1928 . .	—0·6	+1·4	—0·6	*+2·7*	14	21	*18*	*24*	2·70	2·97	2·85
1932 . .	—1·0	—0·2	*+4·1*	+1·8	10	18	*25*	*20*	1·50	3·16	*0·04*
1937* .	—3·5	+4·7	*+3·6*	+0·4	6	31	*27*	*18*	1·32	*0·10*	*0·76*
1938* .	+2·3	+3·6	*+3·6*	*+1·8*	20	25	*26*	*20*	1·05	1·28	*0·73*
1939 . .	—1·6	+3·3	*+5·0*	*+1·4*	18	26	*27*	*19*	2·76	1·21	*0·08*
1940* .	+1·0	—0·1	+0·7	*+2·7*	19	14	*19*	*29*	1·21	2·04	0·73
1941* .	—2·8	+1·9	—1·5	*+3·8*	6	20	14	*26*	4·28	1·93	2·33
Normal monthly mean of max. temp.	102·2	97·9	97·4	92·7							

Table XV

Montgomery

	Departure from normal monthly means for max. temp.				No. of days when max. temp. were above normal monthly means				Rainfall in inches		
	July	August	September	October	July	August	September	October	July	August	September
Good years											
1923 . .	—1·6	—5·0	—0·7	—3·0	11	3	8	14	3·66	5·97	0·42
1924 . .	+0·5	—0·7	—5·3	—1·6	18	10	2	10	4·95	0·69	2·70
1933 . .	—2·3	—8·7	—5·4	—2·5	9	0	2	13	1·50	6·16	1·45
1935 . .	—3·1	—1·7	—0·8	—2·7	9	7	12	8	3·84	1·76	0·00
1936 . .	—5·0	—3·2	—1·8	—1·2	2	10	7	16	3·30	1·89	0·72
Tirak *years (Asterisks indicate medium* tirak *years)*											
1926 . .	—0·1	—3·7	—4·2	—1·7	16	5	4	11	1·93	6·33	1·74
1927* .	—3·7	—2·2	—1·5	—0·9	8	8	10	11	2·68	*0·67*	*0·17*
1928 . .	—1·0	—1·8	—2·7	+0·3	14	12	4	*21*	2·40	4·90	6·82
1932 . .	—1·0	—3·4	+1·8	—0·7	12	4	*24*	*18*	2·00	2·17	*0·15*
1937* .	—3·8	+0·5	—0·2	—3·3	5	17	15	10	2·43	*0·00*	*0·44*
1938* .	+0·7	+0·1	+0·2	—1·3	17	16	15	*16*	*0·93*	*0·80*	*0·59*
1939 . .	—3·2	+1·3	*+2·3*	—0·9	8	22	*23*	*20*	1·85	*0·23*	*0·01*
1940* .	—0·6	—3·3	—1·1	+0·5	18	4	12	*16*	1·55	2·92	*0·19*
1941* .	—2·3	—2·1	—3·3	*+2·3*	8	16	7	*16*	1·19	0·91	1·35
Normal monthly means of max. temp.	103·9	101·1	99·9	95·8							

TABLE XVI

Multan

	Departures from the normal monthly means of max. temp.				No. of days when the max. temp. were above normal monthly means				Rainfall in inches		
	July	August	September	October	July	August	September	October	July	August	September
Good years											
1923	+1·5	—2·3	—1·2	—2·8	17	10	8	17	1·48	3·22	0·00
1924	+6·1	+0·8	—4·6	—0·1	25	17	1	17	1·63	0·48	3·26
1933	+1·4	—3·5	—2·2	—0·2	21	5	9	13	0·73	3·42	1·39
1935	—0·4	—1·7	0·0	—2·6	14	5	14	9	1·09	0·45	0·05
1936	—4·4	—1·4	—2·0	+0·2	3	9	8	21	1·66	1·72	1·77
Tirak *years (Asterisks indicate medium* tirak *years)*											
1926	+3·7	+1·6	—1·4	*+1·7*	22	20	11	*23*	1·51	2·06	0·81
1927*	+0·3	+1·5	*+2·0*	*+3·3*	15	17	*21*	*30*	1·34	0·26	0·21
1928	+0·6	+0·7	+0·4	*+3·7*	19	19	15	*28*	1·84	1·20	*0·01*
1932	+0·7	—1·4	*+4·2*	*+1·3*	12	11	*29*	*20*	1·64	1·55	*0·13*
1937*	—1·6	—0·7	+0·9	—1·5	12	8	*20*	14	1·44	*0·00*	*0·00*
1938*	+1·0	+0·5	+0·6	+0·8	20	14	13	*21*	1·36	1·75	*0·00*
1939	—1·8	+1·9	*+3·6*	—0·2	9	17	*22*	*22*	1·01	*0·06*	*0·00*
1940*	+1·2	—1·2	—1·0	+1·0	21	11	9	*25*	1·79	2·75	*0·02*
1941*	+0·4	+3·4	—1·9	*+4·0*	19	21	12	*29*	1·08	0·16	1·39
Normal monthly mean of max. temp.	104·3	100·9	100·4	95·9							

some exceptions. As for instance, 1926 was a failure year but the temperatures were not above normal at Lyallpur during the two months. But at Multan the month of October was warmer by 1·7°F. than the normal with 23 days of higher temperatures than normal.

In 1937 which was a partial *tirak* year the temperatures for the two months at Multan were not found above normal though they were above normal at Lyallpur. In this particular case the spell of warm weather at Multan occurred from the 15 September up to 10 October. During this period the temperatures were continuously higher than the normal. Thus even though the monthly means for September and October were not above normal the spell of hot weather had occurred at Multan and caused medium incidence of *tirak*.

In Tables XIV-XVI given above for Lyallpur, Montgomery and Multan, three points are to be noticed (1) departure from monthly means from normal maximum temperature in September and October, (2) the number of days when the temperatures were above normal in the same two months, and (3) the rainfall in September. When the departures from normal monthly means are not higher than normal, the number of days above normal would give an indication of the hot spells. It is already pointed out that spells of hot weather are more important than deparutres from monthly means for the increase in water loss from the crop and for the intensification of *tirak*. In Tables XIV-XVI the figures showing either higher monthly means of temperature or the number of days above normal in September-October are italicized. If the monthly means are normal in a *tirak* year, the column for the number of days above normal in September-October should be seen, as they indicate that these months were characterized with spells of hot weather. Side by side the rainfall figures for September should be studied. It may be seen that normal monthly means at Lyallpur for September and October are lower than the normal monthly means for Montgomery and Multan. They are lower by nearly 2·5 degrees. For the plants the temperatures, as they are, are important and consequently *tirak* appears always in a more intensified form at Montgomery and Multan than at Lyallpur. The soils at Montgomery are more saline than at Lyallpur and this is another reason why complaints of *tirak* are more frequent from this district than from other districts. The *tirak* years of 1926 at Lyallpur and of 1926 and 1927 at Montgomery do not either show higher monthly means of maximum temperature or spells of hot weather in September-October. It is not

possible to assign at present any reasons for these exceptions.

Departures from normal monthly means of maximum temperature and the number of days above normal in July and August do not appear to be important in the intensification of *tirak* as the figures for good years and *tirak* years will indicate.

As the nature of weather factors that cause widespread *tirak* in the years of cotton failures could only be studied in terms of spells of hot weather, it was necessary to study the question of correlationship between yields and temperatures from this point of view. When the spells of higher maximum temperatures than normal were taken for this study of exploring the relation between temperatures and yields, it was possible to obtain good evidence that hot weather in the months of September and October was related to low yields of cotton. For this study the degrees above the normal maximum temperatures (average of 10 years) in a spell lasting for eight days or more were taken. It was assumed that a hot spell lasting for eight days in these two months was long enough to cause damage to the crop. It is, however, to be expected that a continuous spell of 16 days does more damage than two separate spells of eight days each separated by a period of normal temperatures. As a study of this relationship was considered important the correlation coefficients were determined with and without eliminating time trends (secular changes).

TABLE XVII

—	Americans only 1921-40		Americans + *Desis* 1914-40	
	Time trends not eliminated	Time trends eliminated	Time trends not eliminated	Time trends eliminated
Lyallpur	—0·4493	—0·1036	—0·2635	—0·2655
Montogomery	—0·4776*	—0·4105	—0·3266	—0·4126*
Multan	—0·7211**	—0·4088	—0·5776**	—0·5566**
Brucepur Farm	—0·1155	—0·2256	..	..
Okara Farm	—0·4958*	—0·4535	..	..
B. C. G. A. Farm	—0·5616*	—0·3985	..	..

The results (Table XVII) showed one common feature that values of the correlation coefficients were negative in all cases. Thus there was a definite indication of a fall in yield as the degrees above normal maximum temperatures in the heat spells in the two months increased. The values of correlation coefficient increased from Lyallpur to Multan tract. This result indicated that high temperatures affected the yields more in the Montgomery and Multan districts than in the Lyallpur district. The normal maximum temperatures are higher in the former districts; the adverse effects of hot spells in these two months on *tirak* and consequently the yields were therefore higher in the Multan and Montgomery districts than in Lyallpur district. The correlation coefficients between the degrees above the normal maximum temperatures in hot spells and the yields of the three farms located in three districts were also negative and the values of coefficients were lower at Brucepur (Lyallpur district) than at the two remaining places.

The intensity of *tirak* under adverse conditions of weather would be determined by the degree of salinity in the subsoil. Salinity in the subsoil is a very variable factor. The injurious effects of salinity on the crop is not directly proportionate to its concentration as it is dependent upon other soil factors. These factors are: physical texture of the soil, its base-exchange capacity, the relative porportions of calcium and sodium ions in exchangeable and soluble forms and the relative amounts of different sodium salts present. The aggravating effect of warm weather during the fruiting stage would thus vary from field to field according as the soil complex varies. The intensity of *tirak* is high on certain soils and low in other soils. The annual variations of *tirak* would not be the same on all soils with a saline subsoil. The intensity of *tirak* would also depend on the general fertility of such soils. The size of the crop, i.e. the vegetative growth made by plants is also an important factor. A well-grown crop on soils with medium salinity is found to suffer the most from *tirak* if the weather is unusually warm and dry at the fruiting stage. The fall in yield is very great on such fertile fields. On soils which are at a low level of fertility the crop is stunted and the yields are, therefore, generally very low even in good years. On such soils the

decrease in yield in a *tirak* year would be of a smaller magnitude. Thus under similar conditions of unfavourable weather, the crops at two nearly situated places would show great variations in the intensities of *tirak* and of yield. This can be illustrated with an example.

The areas situated at a distance of about 20 miles were selected for the purpose. The cotton yields of about 1,000 acres distributed over seven *chaks* (villages) were collected for 1936-40, at Mianchannu and for about the same acreage distributed over six *chaks* at the B. C. G. A. Farm at Khanewal. Observations made in previous years on the cotton crops at these two areas and the analyses of the soils had indicated that the soil conditions in general differed from one another. The soils at Mianchannu were either highly saline or alkaline and were at a low level of fertility with a low base-exchange capacity. It was alkaline in reaction with a low clay content at some places. It is only meant that a major portion of the soils in the Mianchannu area possessed these characteristics. The crop at these areas was in general stunted in growth and showed premature yellowing of leaves and gave low yields.

The soils on the B. C. G. A. Farm were, on an average, of good fertility and of medium salinity. The crops made good growth, reaching a normal to above normal heights. The general level of yield was high. The yields, *chak* by *chak*, for the period 1936 to 1940, are given in Table XVIII. The mean for *chaks* and for years were determined and the coefficients of variability and the standard deviations were calculated.

TABLE XVIII

Yields in md. per acre in different years in different chaks

Chak No.	1936	1937	1938	1939	1940	Mean for *chaks*	S. D.	Coefficient of variability
				Mianchannu				
95	10·59	10·92	9·14	6·45	9·43	9·37	1·64	17·5
126/1	8·12	7·06	6·28	6·52	10·29	7·65	1·68	21·3
125	8·58	6·74	5·88	5·93	7·00	6·83	1·10	16·1
134	9·97	6·79	6·69	5·21	5·69	6·87	1·86	27·1
126/2	6·15	4·72	3·84	4·09	6·76	5·11	1·29	25·1
93	5·55	5·75	4·98	4·29	4·32	4·98	0·68	13·7
126/3	4·87	3·65	2·96	3·99	4·78	4·05	0·80	19·8
Mean for years	7·69	6·52	5·68	5·25	6·90	6·41	1·29	20·1
Per cent deviation from the general mean	+20·00	+1·70	—11·40	—18·10	+7·60	..	..	..
				Khanewal				
86	13·69	9·15	8·29	5·11	14·68	10·18	3·97	39·0
81	11·66	10·55	9·50	3·21	18·41	10·67	5·43	50·9
75	13·65	9·12	9·03	5·44	14·54	10·36	3·74	36·1
82	12·01	7·80	5·61	2·49	15·54	8·69	5·16	59·4
83	12·41	7·83	7·41	2·99	14·35	9·00	4·28	49·8
85	13·63	6·79	6·90	3·80	12·82	8·79	4·25	43·1
Mean for years	12·84	8·54	7·79	3·84	15·06	9·61	4·51	47·3
Per cent deviation from general mean	+33·60	—11·10	—18·90	—60·00	+56·70	..	..	..

The means for *chaks* for the five years is 6·41 for Mianchannu area and 9·61 for the B. C. G. A. Farm. In the best year for the cotton crop in the Punjab (1936) the average yield of seed cotton at Mianchannu was 7·69 md., i.e. 20 per cent above the general mean while at Khanewal it was 12·84 md., i.e. 33·6 per cent higher than the general mean. On the other hand, during the bad year of 1939 the average yield at Mianchannu area was 5·25 md. per acre, i.e. 18·1 per cent below the general mean while at Khanewal the yield had dropped to 3·84 md. per annum, i.e. 60 per cent below the normal mean. Thus annual variations on the Mianchannu area were of a smaller magnitude than the annual variations at the B. C. G. A. Farm. In the last three *chaks* at Mianchannu the yield had fluctuated within 2 md. while at Khanewal the yields fluctuated within a much larger range. The difference between the yields at Khanewal in 1936 and 1939 was nearly 9 md. Thus the cotton crop at Khanewal suffers great damage from *tirak* when the temperatures are high at the fruiting stage. This is the peculiarity of good fertile soils which have medium

salinity in the subsoil. The cotton crop makes vigorous growth on such soils and gives good yields if the month of September or October is not unusually warm. But the well-grown crop with large transpiring surface (leaf area) suffers greatly from water deficit when the temperatures are high and the crop shows symptoms of desiccation. The young and immature bolls crack with immature seeds and poor quality of lint. There is a sudden and rapid change in the physiognomy of the crop. A green, healthy-looking crop gradually exhibits drooping and shedding of leaves. The bolls situated at the topmost parts of the stems and branches suffer most from desiccation while the bolls situated lower down on the branches and which are protected by leaves from direct insolation continue to grow and open normally.

The coefficient of variability was high for *chaks* at Khanewal but was low for *chaks* in Mianchannu area. Similar differences in the standard deviations were found for the *chaks* in the two areas. It was also found that differences between years were highly significant for Khanewal but they were not significant for the Mianchannu area. The variability between the *chaks* at Mianchannu is high as the latter contains some *chaks* with good fertile soils (*chak* Nos. 95, 126/1, and 125). At Khanewal the soil conditions in all *chaks* do not appear to vary widely.

It was pointed out in section I of this investigation that the yields at Khanewal showed great annual variations after the secular changes were eliminated. The depressions in the polynomial curves indicated the years of cotton failures when *tirak* had occurred on an extensive scale. In such soils a correlation between temperatures in September and October and the yields is expected as among other factors that influence the yields; *tirak* is a predominating one. This can be seen from Table XIX where the yields of the B. C. G. A. Farm for good, partially *tirak* and *tirak* years are given along with the temperatures.

TABLE XIX

Year	B. C. G. A. Farm Md. per annum	Departures from normal monthly means of max. temp.		No. of days when temp. were above normal		Rainfall in inches		
		September	October	September	October	July	August	September
				Good years				
1923	14·37	—1·2	—2·8	8	17	0·85	3·08	0·00
1924	15·30	—4·6	—0·1	1	17	2·05	0·12	4·63
1933	12·40	—2·2	—0·2	9	13	0·00	7·43	0·22
1936	12·74	—2·0	+0·2	8	21	0·00	0·75	0·86
				Partial tirak *years*				
1932	8·15	*+4·2*	*+1·3*	*29*	*20*	5·98	2·15	*0·00*
1937	7·67	+0·9	—1·5	*20*	14	0·90	*0·00*	*0·00*
1938	8·24	+0·6	+0·8	13	*21*	1·68	1·32	*0·00*
				Tirak *years*				
1926	6·82	—1·4	*+1·7*	11	*23*	0·00	0·32	*0·00*
1927	3·35	*+2·0*	*+3·3*	*21*	*30*	0·48	*0·00*	0·95
1928	4·92	+0·4	*+3·7*	15	*28*	2·33	+0·37	0·00
1929	3·62	*+3·6*	—0·2	*22*	*22*	0·80	0·00	0·00

The sowing date of the crop would also affect the intensity of *tirak* on soils with saline subsoils. In a previous contribution by Dastur and Mukhtar Singh [1942] it has been conclusively shown that crop sown in June suffers less damage from *tirak* than May-sown crop. This finding has now been confirmed on a very extensive scale on properly replicated experiments on zemindars' lands. *Tirak* was ameliorated on soils with saline subsoils by deferring sowings by one month. The vegetative growth of the plant is reduced by this measure. The reduction in the leaf area of the crop decreases its demand for water and the crop consequently does not suffer from a water deficit to the same extent as a May-sown crop does on the same soil. The reduction in the intensity of *tirak* would vary according to the degree of salinity and temperatures prevailing in the months of September and October and the sowing date.

Observations of the crop, the quantitative determinations of *tirak* by recording the weights of seed cotton per boll on a very large scale, the determination of salinity and other soil properties and the records of temperature in the two months

have brought to light the interrelations of *tirak* with the three factors : salinity, temperature and sowing date, which can now be generalized in the following terms :

1. Under given conditions of sowing time and temperature the resistance of the crop to *tirak* declines as salinity increases.

2. Under given conditions of sowing time and salinity, the resistance of the crop to *tirak* declines as the temperatures in the months of September and October rise above the normal in long spells.

3. Under given conditions of salinity and temperatures the resistance of the crop to *tirak* increases as the sowings are delayed from May to the last week of June.

Thus, whether a crop will suffer from *tirak* or not and also the intensity of *tirak* in a particular field will be determined by the covariations of the three factors under normal conditions of irrigation.

Irrigations may also play a great part in the development of *tirak*. If an irrigation is missed during the hot spell of weather in the two months' *tirak* may develop if the soils are mediumly saline in the subsoil while an irrigation given at a shorter interval than normal at this stage may prevent the development of *tirak* in the same field.

Numerous attempts have been made to correlate the variations in yields of cotton with weather conditions in all cotton-growing countries. As for instance Crowther and Crowther [1935] have shown that in Sudan the variations in cotton yields (1911-31) were associated with rainfall preceding the cotton crop, the yields being low when the rainfall was heavy. Similar studies of cotton yields on relation to weather conditions have been made by Smith [1925], Hale [1933], Fullon [1939] in America and by Kalamkar [1935] in India. But no attempt has so far been made to study the interaction of weather conditions with the soil factors on cotton yields.

Summary

The American cotton plants in the Punjab have been known to suffer from a physiological disease popularly known as *tirak*. The intensity and spread of *tirak* varied from year to year. In 1921, 1926, 1927, 1928 and 1932, *tirak*-affected crop appeared on larger areas than normal and the yields were reduced by 20 to 45 per cent. It was, therefore, attempted to determine the weather conditions that might be responsible for such annual variations in the spread and intensities of *tirak*.

The yields of the Punjab, of three important districts of the Punjab and of three cotton farms located in the three districts for 1921-40 period showed annual variations after the secular variations were eliminated by the use of Fisher's method of polynomial curves. Thus the effect of seasonal factors was visible in the yield series. The years in which *tirak* had appeared coincided with the depressions in the polynomial curves.

The correlation studies between the weather factors singly and in combination and the yield series after elimination of secular trends were made but the results obtained were complex and gave no indication of the weather factors that could be associated with the years of low yields. Any such correlation was also not expected as the variations in yield can occur due to the operation of several factors. The yields depend on the boll numbers and the number of bolls produced per plant would depend on the seasonal conditions and biotic factors operating at different stages of growth. In the Punjab, the additional physiological factor of *tirak* which affects the boll weight also operates and determines the yields. The seasonal factors that may affect the production of bolls may be different from those that may affect the boll size. Thus no direct relationship between weather factors and yield was expected or obtained.

It was however possible to get some idea regarding the nature of weather factors that appeared to increase the incidence of *tirak* in the Punjab-American cottons.

The *tirak* years are characterized by hot September or October. These months are marked with spells of unusually warm weather lasting for ten days or more. Such spells had occurred at any time during these months in all *tirak* years with some exceptions. The monthly means of maximum temperatures were either above the normal monthly mean by 2° to 5°F. or there were spells of warm weather lasting for 10 days or more when temperatures were above normal. Some of these years were also marked with total absence of rain in September.

When the correlation coefficients between yields and the degrees above the normal maximum temperatures (average of 10 years) were determined it was found there was a negative correlation between temperature and yields, and in the case of Multan and Montgomery districts they were either significant or on verge of significance.

The reasons for absence of correlationship between monthly or fortnightly means of maximum temperatures and yields have been explained.

Acknowledgements

The best thanks of the authors are due to Mr. H. R. Stewart, C.I.E., I.A.S., Director of Agriculture, Punjab, for taking keen interest in the progress of the work of this investigation.

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CARBOHYDRATE METABOLISM IN SOME OLEIFEROUS *BRASSICAE*

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(Received for publication on 13 August 1942)

It was first observed by De Luca [1861-62] that as the sugar content of the developing olive diminished, the amount of oil increased, so that when the oil content was at its maximum, the sugar had almost disappeared. Following his pioneer work, various other investigators including Leclerc du Sablon [1896], Gerber [1897], Ivanow [1911], Caskey and Gallop [1931] quoted by Miller, carried out a comprehensive study of the biochemical changes taking place in the oilseeds and confirmed De Luca's findings. Sahasrabuddhe [1932] on niger seed shows that 'the oil is formed in the seed from carbohydrates. Lower saturated acids are formed first and then the higher and unsaturated acids. The change of carbohydrates to fatty acids is brought about by some enzyme present in the developing seed. The free fatty acids are accumulated and these are then transformed by means of an enzyme—esterase—into natural glycerides. The activity of this enzyme is different in different stages and is maximum when the oil percentage is increasing very rapidly.'

The formation of oil in the developing ovules of *toria* (*Brassica napus* L. Var. *dichotoma*, Prain) and *sarson* (*Brassica campestris* L. Var. *sarson*, Prain) has already been studied by Mohammad and Ahmad [1940] and it has been seen that under normal conditions the formation of oil in these crops takes place during a period of 20 to 40 days of the development of the seed after flowering. The part that the various carbohydrates present in the different parts of the plant play in the actual synthesis of fats in the case of *toria* and brown *sarson* crops is a problem which requires elucidation.

For the purpose of this investigation, freshly opened flowers in sufficiently large number were tagged during the mid or full bloom periods of *toria* and brown *sarson* crops, and samples of developing ovules of known ages were obtained for analysis at regular intervals of ten days. Five plants were removed from each plot between 9 and 10 a.m. on each day of sampling and were divided into stem, branches and leaves. These samples were obtained three times during the growing season, viz. (*i*) at the blooming stage, (*ii*) at the fully grown stage, and (*iii*) at maturity. Estimations of reducing sugars, non-reducing sugars and acid hydrolysable carbohydrates were carried out in the case of each sample. For these estimations the method of Shaffer Hartmann as modified by Ramji Narain [1932] was followed. The results obtained during these investigations are summarized in Tables I and II from which the following general conclusions can be drawn:

(*a*) As will be seen from the figures given in Table I, there is a slight variation in the carbohydrate content of the developing ovules, especially in the beginning of the seed development. The differences may be attributed either to the sampling errors or to the seasonal variation. This, however, is of little consequence, for the general conclusions based on two years data, for which the results are presented, show the same trend.

The total carbohydrates in the developing ovules of both *toria* and brown *sarson* increase from the beginning of seed development till about 20 days after, when they reach their maximum. Thereafter a decrease goes on for another 20 days so that at the age of 40 days a considerable decrease in the total carbohydrate content takes place after which the decrease is not very appreciable. For example the percentage of total carbohydrates expressed on dry basis (average of two years) in the developing ovules at the age of 40 days in *toria* and brown *sarson* falls down to 10·44 and 10·28 from 32·20 and 40·94 in 20 days old seed respectively (Table I). It has already been reported [Mohammad and Ahmad, 1940] that the fat exhibits exactly opposite behaviour and a major portion of it is deposited in what has been termed as the 'critical period' of oil formation, viz. 20-40 days of the development of the seed after flowering. This phenomena of interdependence and mutual relationship of carbohydrates to the formation of fats is in line with the findings of De Luca [1861-62], Leclerc du Sablon [1896], Gallop [1927] and Rushkovskaii [1930] concerning the development of olive, walnut and almond, cotton and sunflower, respectively.

(*b*) Of the total carbohydrates that show a decrease, the reducing sugars are the first to undergo a change and are followed by acid-hydrolysable carbohydrates. For example, the percentage of reducing sugars expressed on dry basis (average of two years) decreases to 2·77 and 3·04 in seeds 30 days old from 11·07 and 14·54 in 20 days old seeds of *toria* and brown *sarson* respectively (Table I). Thereafter the decrease is not so marked. The acid-hydrolysable

TABLE I

Carbohydrate content in the developing ovules of toria *and brown* sarson (*average of all treatments*), *in 1940-41 and 1941-42*

Name of crop	No. of days after flowering	Percentage on dry basis: Alcohol soluble sugars: Reducing sugars 1940-41	1941-42	Average	Non-reducing sugars 1940-41	1941-42	Average	Acid hydrolysable carbohydrates 1940-41	1941-42	Average	Total carbohydrates 1940-41	1941-42	Average	Moisture percentage 1940-41	1941-42	Average
Toria	10	6·39	4·82	5·60	1·51	2·50	2·00	12·39	20·90	16·64	20·29	28·22	24·25	77·0	74·0	75·5
	20	12·62	9·53	11·07	2·90	2·60	2·75	14·32	22·44	18·38	29·84	34·57	32·20	80·7	82·7	81·7
	30	3·18	2·37	2·77	2·62	2·01	2·31	14·62	9·66	12·14	20·42	14·04	17·23	72·3	79·9	76·1
	40	1·17	1·42	1·29	2·47	0·85	1·66	8·73	6·25	7·49	12·37	8·52	10·44	63·4	67·1	65·2
	50	0·49	0·55	0·52	2·16	1·24	1·70	7·47	3·37	5·42	10·12	5·16	7·64	52·4	61·8	57·1
	60	1·03	0·77	0·90	1·95	0·79	1·37	4·66	3·57	4·11	7·64	5·13	6·38	45·1	51·7	48·4
	70	0·98	0·78	0·85	1·56	0·87	1·21	4·27	3·39	3·83	6·76	5·04	5·90	34·6	32·8	33·7
Brown *sarson*	10	9·50	7·35	8·42	2·57	2·23	2·40	13·05	7·71	10·38	25·12	17·29	21·20	79·1	75·0	77·0
	20	16·43	12·65	14·54	4·23	3·89	4·06	22·78	21·90	22·34	43·44	38·44	40·94	81·6	82·4	82·0
	30	3·65	2·43	3·04	3·92	1·69	2·80	11·72	10·62	11·17	19·29	14·74	17·01	71·1	77·1	74·1
	40	1·26	1·80	1·53	1·82	0·80	1·31	7·68	7·20	7·44	10·76	9·80	10·28	49·3	65·6	57·4
	50	0·71	0·67	0·79	1·96	0·94	1·45	4·37	4·94	4·65	7·04	6·75	6·89	10·6	34·8	22·7
	60	1·06	1·57	1·31	2·64	0·99	1·81	5·50	5·55	5·52	9·20	8·11	8·65	6·6	7·5	7·0

TABLE II

Carbohydrate content in various parts of toria *and brown* sarson (*average of all treatments*) *at different periods of their growth in 1940-41 and 1941-42*

Name of crop	Stage of sampling	Name of sample	Percentage on dry basis: Alcohol soluble sugars: Reducing sugars 1940-41	1941-42	Average	Non-reducing sugars 1940-41	1941-42	Average	Acid hydrolysable carbohydrates 1940-41	1941-42	Average	Total carbohydrates 1940-41	1941-42	Average	Moisture percentage 1940-41	1941-42	Average
Toria	Plants at blooming stage	Stem	5·68	5·70	5·69	3·03	2·54	2·78	4·34	2·61	3·47	13·05	10·85	11·95	88·2	89·1	88·6
		Branches	7·81	7·21	7·51	2·89	1·81	2·35	5·38	2·71	4·04	16·08	11·73	13·90	87·5	87·7	87·6
		Leaves	1·66	2·61	2·13	1·25	0·87	1·06	2·47	1·98	2·22	6·00	5·46	5·73	85·8	83·9	84·8
	Fully grown plants	Stem	1·85	1·21	1·53	1·34	0·51	0·92	4·77	2·96	3·86	7·96	4·68	6·32	76·6	84·6	80·6
		Branches	4·14	1·94	3·04	1·25	0·82	1·03	4·84	3·84	4·34	10·23	6·60	8·41	76·2	84·2	80·2
		Leaves	2·70	1·49	2·09	1·79	1·03	1·41	3·45	2·78	3·11	7·94	5·30	6·62	84·8	85·7	85·2
	Mature plants	Stem	1·25	1·00	1·12	0·70	0·69	0·69	6·38	2·44	4·63	8·78	4·18	6·45	76·1	79·5	77·8
		Branches	2·01	1·14	1·57	0·95	0·80	0·87	6·99	2·80	4·89	9·95	4·74	7·34	71·3	78·3	74·8
		Leaves	1·31	1·17	1·24	1·02	0·72	0·87	4·32	3·22	3·77	6·65	5·11	5·88	78·9	81·5	80·2
Brown *sarson*	Plants at blooming stage	Stem	10·09	5·33	7·71	3·79	3·37	3·58	6·00	5·72	5·86	19·88	14·42	17·15	90·7	92·7	91·7
		Branches	11·79	5·62	8·70	3·49	2·32	2·90	6·05	5·61	5·83	21·33	13·55	17·44	90·3	90·7	90·5
		Leaves	2·65	2·75	2·70	2·30	1·67	1·98	4·81	2·94	3·87	9·76	7·36	8·56	87·3	88·3	87·8
	Fully grown plants	Stem	1·52	1·13	1·32	1·19	1·44	1·31	7·10	4·16	5·63	9·81	6·73	8·27	80·1	84·9	82·5
		Branches	2·68	2·54	2·61	1·06	1·60	1·33	8·13	4·21	6·17	11·87	8·35	10·11	74·7	87·3	81·0
		Leaves	1·99	1·58	1·78	1·79	0·83	1·31	6·89	4·16	5·52	10·67	6·57	8·62	84·1	88·1	86·1
	Mature plants	Stem	0·68	0·99	0·83	0·69	1·10	0·89	8·08	4·24	6·16	9·45	6·33	7·89	76·7	79·9	78·3
		Branches	0·92	0·63	0·77	0·45	1·32	0·88	6·71	4·40	5·50	8·08	6·35	7·21	70·8	75·4	73·1
		Leaves	0·57	1·14	0·85	0·35	1·31	0·83	6·09	5·47	5·78	7·01	7·92	7·46	37·1	72·5	54·8

carbohydrates are present in the highest concentration at the age of 20 days of the seed and a decrease in these is comparatively slow as compared with the reducing sugars. For examples the percentage of acid-hydrolysable carbohydrates expressed on dry basis (average of two years) in 40 days old ovules falls down to 7·49 and 7·44 from 18·38 and 22·34 in 20 days old ovules in *toria* and brown *sarson* respectively.

(*c*) The non-reducing sugars which are present in much smaller amounts exhibit a similar change. The percentage of these has been found to vary between 1·21-2·75 and 1·31-4·06 in *toria* and brown *sarson* respectively (average of two years) during the entire developing period of the seed (Table I).

(*d*) In the leaves the total carbohydrates remain practically constant throughout the growing period. A slight fall in the reducing sugars takes place as the plant advances in age but this fall is levelled up by a slight increase in the concentration of acid-hydrolysable carbohydrates. This may be attributed to the fact that the leaves do not appear to be the chief storing organs of carbohydrates and the increase in the acid-hydrolysable carbohydrates in the latter stages may be due to the inefficiency of the hydrolysis, probably owing to the drying of leaves.

(*e*) In the stem and branches the percentage of total carbohydrates is maximum at the blooming period of the plants in both the crops, the reducing sugars being in the highest concentration. Further, as the plant grows to its normal height a considerable reduction in the concentration of reducing sugars occurs, the percentage of acid-hydrolysable carbohydrates, however, remains practically the same. Thus the percentage of total carbohydrates expressed on dry basis (average of two years) in fully grown plants in stem and branches in *toria* decreases to 6·32 and 8·41 from 11·95 and 13·90 respectively at blooming stage. Similarly in brown *sarson* the percentage of total carbohydrates (average of two years) in fully grown plants in stem and branches decreases to 8·27 and 10·11 from 17·15 and 17·44 at blooming stage (Table II). This fall in the carbohydrates is evidently due to the continuous movement of these from the stem and branches to the developing seed. Afterwards the decrease is not much marked. It will be interesting to note that at the blooming stage brown *sarson* has 43·5 and 24·7 per cent higher quantities of total carbohydrates in stem and branches respectively as compared with *toria*, a fact which probably makes brown *sarson* better liked for edible purposes. It will also be seen that the amounts of total carbohydrates in stem and branches determined at whatever stage of growth are highly correlated with each other.

Acknowledgements

The work reported in this paper forms a part of the programme of work relating to the Oilseeds Research Scheme in the Punjab, partly financed by the Imperial Council of Agricultural Research and partly by the Punjab Government and the authors take this opportunity of gratefully acknowledging the Council's help in this respect.

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VARIETAL COMPOSITION OF THE SUGARCANE CROP IN INDIA IN 1941-42

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(Received for publication on 29 September 1942)

This paper has been prepared under the instructions of the Imperial Council of Agricultural Research and is intended to be a revision of the varietal portion of the Council's *Miscellaneous Bulletin* No. 34 entitled 'Some practical results of sugarcane research in India'. It brings the information up to date and inclusive of the 1941-42 crop.

The data presented here have been kindly furnished by the Departments of Agriculture of the provinces and States concerned. A detailed survey, variety by variety, is no easy matter, particularly for such large areas as the United Provinces. Even then as many as over 500,000 acres (exclusive of indigenous varieties) have been surveyed in the United Provinces. Similar surveys have also been made in quite a few other tracts and suitable information is available practically for each district. But in certain important provinces no such detailed surveys appear to have been made and the figures given are only tentative. An attempt has been made to include in this paper the salient features of the more important varieties and their distribution.

Regional distribution of varieties

The United Provinces (1,755,178 acres)

For varietal distribution it would be convenient to divide this province into three separate tracts as the relative importance of varieties is different in each. In western United Provinces (752,100 acres) the first position is now occupied by Co 312 (51 per cent). Next come Co 244 (13 per cent), Co 331 (9 per cent) and Co 421 (7 per cent). The variety Co 244 is confined to the western tract of the U. P. and that too mostly in the Bulandshahr district.

In the central United Provinces (445,500 acres) the first position again goes to Co 312 (33 per cent). Next in order are Co 290 (23 per cent), Co 331 (15 per cent), Co 421 (10 per cent) and Co 313 (9 per cent). The importance of Co 290 in the U. P. is confined chiefly to the central tract.

As regards eastern United Provinces (557,500 acres) the first position is held by indigenous *desi* varieties (46 per cent) and then comes Co 213 (16 per cent). These are followed by Co 421 (8 per cent), Co 312 (7 per cent), Co 331 (6 per cent) and Co 370 (5 per cent). A feature of the eastern U. P. is that Co 213 and the *desi* varieties are still being grown by the cultivators.

The *desi* varieties occupy about 7 per cent of the area in western U. P. and a similar percentage in the central U. P. also. But they dominate the position in Azamgarh, Fyzabad and Ballia districts of eastern U. P. on account of which their percentage in the eastern tract is as much as 46. Taking U. P. as a whole the indigenous varieties occupy about 9 per cent of the area.

Co 213 has lost the dominant position which it occupied in these provinces a few years ago. This decline is due to its susceptibility to red rot of which disease there was a severe epidemic recently. It is likely that this variety will disappear from the U. P. in the next few years. It now occupies 2 per cent, 2 per cent and 16 per cent of the area in western, central and eastern U. P., respectively. Taking U. P. as a whole its area has dwindled to 10 per cent.

Bihar (370,600 acres)

In the white sugar belt of Bihar (north Bihar—220,600 acres) the first position is now held by Co 313 (60 per cent). Next comes Co 299 (21 per cent). The varieties Co 213 and Co 210, which till recently were the dominant canes, now occupy between themselves only about 16 per cent of the area. The indigenous canes of Bihar are now mostly extinct and the area under them has fallen to an insignificant figure.

In areas south of the river Ganges (south Bihar—130,000 acres) the varietal position is distinctly different. Here Co 331 is the main variety occupying 80 per cent of the area. Other varieties are Co 313 (about 15 per cent) and Co 213 (5 per cent), the last mentioned being mostly as ratoon. There are about 20,000 acres under sugarcane in the Chota Nagpur tract of Bihar. Here also Co 331 is the main variety (70 per cent) followed by Co 213 which occupies the rest of the area.

The Punjab (457,542 acres)

In this province no single variety is exclusively grown in any particular district. The three or four more important varieties are met with practically in each district. The indigenous *desi* canes which previously covered 50 per cent of the

sugarcane area are now found relegated to the second position (25 per cent). The dominant cane at present is Co 285 with 39 per cent of the area under it. The other canes are Co 223 (12 per cent) and Co 312 (10 per cent). The most important indigenous cane, Katha, still occupies 91,000 acres. Co 421 which has recently been given out to cultivators occupies 2,500 acres.

Bengal (313,900 acres)

Co 213 is still the dominant cane in this province and occupies about 75 per cent of the area. It is, however, losing in popularity on account of its susceptibility to red rot and is being replaced by other varieties. White Tanna (12 per cent) is still holding its own because of relative hardiness and freedom from insect pests and red rot. The indigenous canes like Ikri and Khagri occupy 8 per cent of the sugarcane area in the province.

Bombay (88,762 acres)

The most important cane area in this province is the Deccan Canal tract (60,200 acres). The first position goes to Co 419 which has now come to occupy 50 per cent of the area. Next in importance is POJ 2878 (30 per cent). The local thick cane variety Pundia has now been reduced to the third position (18 per cent).

The second tract in this province is the Southern Mahratta region (24,300). Here Pundia holds the dominant position, particularly in the Belgaum and Dharwar districts. In the Kanara district, however, Red Mauritius is the main cane.

The third tract of this province is the Gujarat region (4,200 acres) which, besides the real thick canes, grows the medium class of canes like Co 213. This variety (Co 213) now occupies 75 per cent of the area. The other canes now grown are POJ 2878, Khajuria, Co 413 and Co 419.

Madras (113,022 acres)

For the purpose of this paper the districts of Vizagapatam, east and west Godavari, and Kistna have been termed north Madras (37,100 acres). In this tract Co 419 has now come to occupy the first position (40 per cent). Next comes Co 213 (24 per cent). The other canes are Purple Mauritius (9 per cent), J 247 (247 B—9 per cent) and Co 421 (5 per cent). In Kistna district sugarcane is a new crop introduced not long ago in connection with the sugar factory at Vuyyur.

In the central Madras tract (50,200 acres) the Chittoor, north Arcot, south Arcot, Salem and Trichinopoly sugarcane areas have been included besides the small areas in Madura and Tanjore. Here also Co 419 occupies the first position (36 per cent). Next in importance is Co 281 (21 per cent). This is the only tract in the whole of India where Co 281 is grown. Other varieties are J 247 (247 B—14 per cent) and POJ 2878 (8 per cent).

The districts of Coimbatore, South Kanara, Bellary and Anantapur have been grouped as western Madras (25,700 acres). The first position goes to the local thick cane varieties (27 per cent). Next in order are Co 419 (20 per cent), Co 290 (20 per cent), Co 413 (16 per cent), and Red Mauritius (11 per cent). Of these Co 290 is important in the Bellary district, Co 413 in the Coimbatore district and Red Mauritius in the South Kanara district. The local varieties Hotte Kabbu, etc. still occupy an important position in Bellary and Anantapur districts.

The North-West Frontier Province (95,770 acres)

The sugarcane area in this province has rapidly risen to 95,700 acres from 52,000 acres three years ago. The maximum cane area is in the Peshawar valley where Co 290 (90 per cent) is the dominant cane. The local thick cane known as Peshawari Pounda is now restricted mostly to the vicinity of towns. Co 213 and Co 210 are grown to a small extent in Hazara. The recently introduced varieties are Co 312 for mid-season crushing and Co 313 for early crushing near the factory zone.

Assam (40,500 acres)

The local thick canes such as Magh, Teli and Bogapura and the indigenous thin cane Khagri are still grown to a fair extent in this province. These occupy roughly 65 per cent of the area. POJ 2714 and POJ 2878 are grown to the extent of about 12 per cent. Other exotic varieties like Striped Mauritius cover 19 per cent of the area. The rest of the area is under Co canes like Co 213 and Co 419.

The Central Provinces (31,000 acres)

In these provinces Co canes occupy about 45 per cent of the area. The more important Co canes are Co 237, Co 312 and Co 313. Co 219 and Co 290 are losing in popularity.

The local thick canes like Pounda and Pachrangi together with the indigenous thin canes such as Khari, occupy 33 per cent of the area. The exotic varieties like Ashy Mauritius, Striped Mauritius and POJ 2878 have under them about 22 per cent of the area.

Orissa (35,000 acres)

Co 213 (89 per cent) is still the main cane in this province. Co 421 (8 per cent) is just coming into importance. Round about Aska J 247 (247 B) still persists and occupies about 400 acres.

Sind (9,000 acres)

The first improved variety introduced in this province a few years ago was Co 213. It has made

satisfactory progress and now occupies 35 per cent of the total area. The other improved varieties are Co 312 (20 per cent), Co 421 (15 per cent) and Co 331 (5 per cent) which are popular with the sugar factory at Mahottanagar. The rest of the area is mostly under the local thick cane varieties like Red Thick, Sukkur White and Lahori Paunda, the last mentioned mostly for chewing purposes.

Mysore (52,841 acres)

In this State the improved varieties occupy nearly 50 per cent of the area. The chief among these is HM 320 (44 per cent) which is the dominant cane in the Mandya district where the factory is located. It is also grown in all the other districts to a more or less extent. The local thick canes—Pattapatti and Rasthali—cover 39 per cent of the area and are the dominant canes in Shimoga, Kolar and Bangalore districts. The local thin cane Cheni occupies 11 per cent of the area and is important in Hassan and Mysore districts. Of the exotic varieties, Red Mauritius occupies about 400 acres. The Coimbatore canes are Co 290 and Co 419. The former is being replaced by HM 607 and HM 661 and the latter occupies only about 100 acres.

Hyderabad (46,500 acres)

The local thick cane varieties like Pundia occupy the first position (45 per cent) in this State and are important in the Bidar, Osmanabad and Raichur districts. Next in importance is POJ 2878 (21 per cent) which is the leading cane in the Nizamabad district where the sugar factory is located. It is also important in the Aurangabad district. Other varieties are Co 290 (19 per cent) and Co 213 (10 per cent).

Baroda (3,700 acres)

In this State the dominant cane is POJ 2878 (69 per cent). The next important cane is Co 213 (13 per cent). The various local thick cane varieties occupy 10 per cent of the area.

Kashmir (5,000 acres)

In this State in the extreme north, cane is confined mostly to the Jammu and Kathua districts where the conditions are more or less similar to the Punjab. The cane varieties also are those which are found in the Punjab. Co 285 occupies the first position (50 per cent). The other canes are Co 312 (15 per cent) and Co 313 (10 per cent). Like the Punjab, the thin indigenous canes occupy the second position (20 per cent.)

Varieties and their behaviour

Desi *or indigenous varieties*

These canes (which are indigenous to India and belong to *Saccharum Barberi*) are still of sufficient importance in certain tracts. Taken together they occupy the third position among varieties in point of acreage (258,000 acres). The following are the more important of these still persisting in cultivation.

Katha. The area under this cane is steadily decreasing but it still occupies about 91,000 acres in the Punjab. The special characteristics on account of which it finds favour are that it is an early cane capable of being crushed in October-November. It also serves as fodder whenever there is scarcity of fodder.

Pansahi, Reohra and Hemja. These canes occupy about 23 per cent of the area in eastern United Provinces chiefly in the districts of Azamgarh, Fyzabad and Ballia.

Dhaur, Matna and Chin. These are grown to a certain extent in western United Provinces chiefly in the Bijnor and Moradabad districts.

Cheni. The variety known as 'Ganda Cheni' still occupies about 6,000 acres in Mysore (mostly in the Hassan district). It persists because of its resistance to drought and to salinity in the soil.

Local thick cane varieties

These belong to *Saccharum officinarum* and are of importance in Bombay, Hyderabad, Mysore, Assam and Madras. They are also grown for chewing purposes near towns in north India. The total acreage occupied by them is about 140,000 acres. The most important member of this group is Pundia of Bombay which is grown fairly extensively in the Deccan Canal and Southern Mahratta region as also in Hyderabad. Pattapatti which is a striped cane but similar in other characters to Pundia is the main local cane in Mysore. The local varieties in Assam are Magh, Teli and Bogapura. In Madras the most important local variety is Hotte Kabbu—a cane similar to Pundia. Other canes which belong to this group and are in minor cultivation include Rasadali which is grown in Mysore, Madras and Bombay ; and Dacca Ganderi and Shamsara in Bengal. The canes grown for chewing in north India are commonly called *paunda*.

Exotic varieties

These are the canes obtained from Java, Mauritius and Barbados from time to time and occupy at present about 119,000 acres in India. The most important of these now is POJ 2878 occupying about 40,000 acres and grown in Bombay, Hyderabad, Madras and Assam. Next in importance are White Tanna (which still occupies about 36,000 acres in Bengal), J 247 (247 B) occupying about 10,000 acres in north and central Madras and Red Mauritius occupying about 6,000 acres in Madras, Bombay and Mysore. The acreage under Purple Mauritius in north Madras has dwindled to about 3,500 acres and that under B 208 to less than

1,000 acres. Fiji B which is the same as the famous Badila has lost its former importance in central and western Madras. It now occupies about 2,000 acres. Other canes which require mention are S riped Mauritius in Assam and parts of Madras, POJ 2714 only in Assam, and EK 28 in the Deccan Canal tract.

Hebbal Mysore canes

These canes have been bred at the Hebbal Farm of the Mysore Station. Of these the most important is HM 320 which occupies about 23,000 acres in Mysore and is popular both as a cultivator's cane and as a factory cane. HM 544 is still popular in the Bangalore and Kolar districts occupying about 600 acres. On account of its late maturity the area under this variety is gradually going down.

The new HM canes of promise are HM 645, HM 647 and HM 661. Of these HM 645 resists drought and is likely to replace the indigenous cane Cheni. HM 647 resists alkalinity in soil while HM 661 is an all-round good cane and is expected to replace HM 320.

Coimbatore canes

The following are the more important of the Co canes and are dealt with in the order of the area occupied by them.

Co 213. Both in the United Provinces and Bihar this cane has lost the dominant position which it once occupied. The chief factor responsible for its downfall is its susceptibilly to red rot. It is likely to be replaced altogether in the U. P. and Bihar by other suitable varieties. It is, however, still the dominant cane in Bengal and Orissa, where also the indications are that ultimately it may be replaced by other varieties.

Co 313. This is now the dominant cane in Bihar having largely replaced Co 213. It is also being grown in the United Provinces and the Punjab. In Bihar the points in its favour are heavy tonnage, superior juice quality, wide range of adaptability and exceptional field resistance to red rot. In the U. P. also it is an early variety with fair yield but is susceptible to mosaic, drought and waterlogging. In the Punjab it is being recommended in place of Katha because of its earliness and for the fact that it does not deteriorate in quality even when crushed late. It is, however, unable to stand shortage of irrigation as much as Co 285 and Co 312 and requires better conditions of soil and manure.

Co 312. It is very popular all over the United Provinces and now occupies the dominant position in the western and central parts. It yields very well, is of medium maturity and has moderate manurial requirements. Its drawbacks are its tendency to lodge under rich conditions and susceptibility to mosaic. Its ratoons are susceptible to mosaic, smut and white-fly. In the Punjab it now occupies the third position among varieties in cultivation and is found to be a late-maturing variety. It withstands drought and gives very heavy yields. It is, however, highly susceptible to insect pests, frost and diseases, especially pyrilla and red stripe.

Co 285. This is now the dominant cane in the Punjab. It has the same qualities of resistance to frost, drought, insect pests and diseases and ability to grow under varied soil conditions as Co 205 which it has replaced, but it is better than Co 205 in yield and quality of produce. It is a very good ratooner. Its defects are late maturity and high fibre content on account of which it is not favoured by mills. It is also grown in the Jammu tract of the Kashmir State where again it is the dominant cane.

Co 331. A hard-rinded, late-ripening cane with good germination and tillering. It gives good yields and has particularly erect habit. It is grown in the United Provinces as also in south Bihar. In the U. P. it is fairly resistant to drought, waterlogging and top-borer but very susceptible to white-fly. It is also showing susceptibility to red rot and wilt, particularly in eastern U. P. In south Bihar it is the dominant cane occupying 80 per cent of the area. There it gives high tonnage and is exceptionally suitable to paddy lands and is resistant to borer pests. It is, however,showing susceptibility to red rot and because of this the area under it is likely to decrease.

Co 290. This cane holds the dominant position in the North-West Frontier Province occupying as much as 90 per cent of the area. It scores over the local *pounda* (which it has replaced) in vigour of growth and ratooning capacity and its ability to grow under a wide range of soil conditions including waterlogged and alkaline soils. Another important point is its relative resistance to red rot. In the United Provinces the importance of this cane is restricted mostly to the Pilibhit and Bareilly districts. It has gone down in area in the Bombay province where it has practically been replaced by Co 419.

Co 299. Till recently this cane was in favour in Bihar as the first cane of the season for starting the mills. The acreage under it has diminished from 29 per cent to 21 per cent due to low tonnage, difficult trashing habit and recent susceptibility to red rot. Chiefly because of its susceptibility to red rot the area under it is likely to decrease still further.

Co 421. This thick-medium cane distributed from Coimbatore relatively recently (1934) has rapidly come to occupy about 71,000 acres distributed over various parts of India like the

United Provinces, the Punjab, Bengal, Orissa and parts of Madras. Among the Coimbatore varieties this is the most widely distributed cane next to Co 213. In the U. P. it is an all-round good, early mid-season cane with vigorous germination and growth. It has done well all over the U. P. and is less damaged by wild animals than Co 312 and its habit is also better than that of Co 312. It possesses a high degree of resistance to borers and other diseases but it is susceptible to wilt. It responds very well to intensive cultural methods. In the Punjab also Co 421 is a good competitor of Co 312 both in yield and quality of produce under better conditions of soil, manure and water. It is not a cane for poor soils in the Punjab. It scores over Co 312 in its erect habit and high resistance to insect pests and diseases.

Co 419. Though the area under this variety is about 69,000 acres and it thus seems to occupy a fairly low position in the scale of varieties, it is in reality the most important cane in the Bombay and Madras provinces. In Bombay-Deccan it is easily the most outstanding cane both from the standpoint of the sugar factories and the cultivators. It is a very heavy-yielding variety with *gur* of moderate quality. It grows well over a variety of soil conditions in tropical India including alkaline soils. It lodges somewhat badly and the canes are brittle and tend to break easily. It is susceptible to pyrilla and mealy bugs.

It is popular in Madras also for the same characteristics as mentioned above, viz. heavy yields, relative drought resistance and ability to grow under a wide range of soil conditions.

Co 223. It is still grown in about 56,000 acres in the Punjab. It is hardier than Co 213 and ratoons well, but is later in ripening and is susceptible to frost, insect pests and diseases. Because of its relatively low yield as compared to such canes as Co 285 and Co 312 which are becoming popular, the area under it is likely to diminish.

Co 244. This cane is popular with the cultivators in western United Provinces, particularly in the district of Bulandshahr and is also grown to a certain extent in the Punjab. It is a thin late-ripening cane well suited to poorer lands but lodges badly under richer conditions.

Co 356. This is a sugarcane-sorghum hybrid. In Bihar, where it had been released for general cultivation, its erratic performance, late maturity and comparatively lower sucrose have stood in the way of its general acceptance. In the United Provinces there are about 20,000 acres under it chiefly in eastern U. P. and the Terai. It is a thickish mid-season variety, poor in germination and tillering and with high water and manurial requirements. It is not suitable for comparatively drier tracts. It possesses high resistance to borers and other pests.

Co 205. Because of its impure juice which gives *gur* of an inferior quality with high mineral contents and because it matures very late and is very fibrous, this (the first improved cane given out to the Punjab farmers) has now been dropped from the list of approved canes by the Punjab Agri ultur Department. There are still about 19,000 acres under it in the Punjab, chiefly in Rohtak, Gurgaon and Karnal districts.

Co 370. This cane figures only in eastern United Provinces where there are about 14,700 acres under it. It is a mid-season variety with good habit and fair yields.

Co 210. It used to be one of the leading canes in north Bihar but has now, because of its susceptibility to red rot, suffered the same fate as Co 213. Together with Co 213 it now occupies only 16 per cent of the area in north Bihar. It is, however, still grown to a certain extent in the Central Provinces where it is proving quite hardy.

Co 281. This cane has now established itself in the factory area in the south Arcot and neighbouring districts of central Madras where it occupies about 10,000 acres.

Co 413. It is quite a favourite in the Coimbatore district of Madras where it occupies about 45 per cent of the area. It is also grown to a certain extent in the Gujarat tract of Bombay.

Co 214. This cane which was mentioned in the last Bulletin is now practically non-existent in Bihar where alone it was much appreciated by the factories in the earlier years.

Co 360. This variety which had shown some promise in the Bombay-Deccan is not now in favour because of its lodging habit and susceptibility to mealy bugs.

Other Co canes of minor importance

The following Co canes which are given in serial order occupy as yet only small areas.

Co 301. This cane occupies about 4,000 acres in the United Provinces. It may be mentioned that it has been released for commercial planting in South Africa.

Co 341. This cane occupies about 1,500 acres in the United Provinces.

Co 349. Like Co 281 this cane is also of some importance in the factory area in South Arcot district of Madras. There are about 2,000 acres under it.

Co 385. This is an early cane in the U. P. occupying about 3,000 acres. In Bihar it is grouped along with Co 313 but it is better in tonnage and juice quality.

Co 393. It occupies about 5,000 acres in eastern United Provinces, and is also promising in Bihar.

Co 395. It is of minor importance both in the U. P. and Bihar.

Co 508. This is an early-ripening cane but gives low yields. It is as yet free from red rot in Bengal.

Co 513. It has done well in north Bihar and bids fair to become the main season cane suiting a variety of conditions. It is, however, at its best in well-drained heavy loams.

New promising canes

Co 453. In south Bihar, this cane is extremely promising at the departmental farms as also at co-ordinated centres of the factories. It is equal in tonnage and superior in juice quality to Co 331. It has shown some promise in the experimental stations in the United Provinces and also in South Africa.

Co 527. It has been distributed for commercial planting in Bengal where it is an early medium cane with fairly good tonnage. It is reported to be promising at experimental stations in a few other provinces also.

Co L 4, 5 and 9 are said to be promising in the Punjab ; Co 545, Co K 26 and Co S 86 in the United Provinces ; and Co 539, Co 543 and BO 4 in Bihar. Certain seedlings called ORB seedlings are being multiplied at Cuttack for further tests. In Bombay Co 426, Co 428 and Co 443 are showing promise.

ACREAGE AND PERCENTAGE AREA UNDER IMPORTANT VARIETI

Varieties	United Provinces 1,755,178 (Verified area—680,856)						Punjab 457,500		Bihar 370,600						Bengal 313,900		Madras 113,022						North-West Frontier Province 95,700	
	West 752,100		Central 445,500		East 557,500				North 220,600		South 130,000		Chota Nagpur 20,000				West 25,700		Central 50,200		North 37,100			
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Co 213 . .	5,076	1·8	2,329	1·9	45,334	15·7	14,102	3·0	17,648	8·0	6,500	5·0	6,000	30·0	235,000	75·0	...	...	1,000	2·0	8,900	24·0	900	1
Co 312 . .	138,854	51·3	40,710	33·4	19,654	6·8	45,198	10·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 313 . .	11,529	4·2	10,525	8·6	9,920	3·4	15,590	3·0	132,360	60·0	19,500	15·0	...	...	...	...	...	...	...	...	...	...	...	..
Co 285 . .	...	...	...	...	...	...	180,127	40·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 331 . .	22,206	8·2	18,299	15·0	16,635	5·7	...	...	...	...	104,000	80·0	14,000	70·0	...	...	...	...	...	...	...	...	...	..
Pansahi and other *desi*	18,946	7·0	8,055	6·6	132,674	46·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 290 . .	1,524	0·6	27,525	22·6	2,800	1·0	...	...	...	...	...	...	...	...	...	...	5,100	20·0	...	...	...	...	86,000	90
Pundia and other *desi*.	...	...	...	...	...	...	8,812	2·0	...	...	...	...	...	...	3,000	1·0	6,900	27·0	2,000	4·0	700	2·0	1,900	2
Exotics .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	37,600	12·0	3,300	13·0	16,000	32·0	5.100	14·0	...	..
Katha and other *desi*	...	...	...	...	...	...	107,853	24·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 419 . .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,100	20·0	18,000	36·0	14,000	40·0	...	..
Co 421 . .	19,566	7·2	11,597	9·5	24,392	8·4	2,583	0·6	...	...	...	...	...	...	...	...	500	2·0	500	1·0	1,900	5·0	...	..
Co 223 . .	...	...	...	...	...	...	56,845	12·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 299 . .	...	...	...	...	...	...	...	...	46,300	21·0	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 244 . .	34,490	12·7	...	...	...	...	3,190	0·7	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
H M 320 .	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	250	1·0	...	...	...	...	...	..
Co 356 . .	7,592	2·8	1,383	1·1	11,322	3·9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 205 . .	...	...	...	...	...	...	19,515	4·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Co 370 . .	...	...	105	0·1	14,653	5·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..
Other varieties	11,211	4·1	1,080	0·8	10,870	3·7	3,600	0·7	24,200	11·0	...	...	...	...	38,000	12·0	4,400	17·0	12,500	25·0	6,000	15·0	7,000	7

N SUGARCANE TRACTS OF INDIA—1941-42

Bombay 88,700						Mysore 52,800		Hyderabad 46,500		Assam 40,500		Orissa 35,000		Central Provinces 31,000		Sind 9,000		Kashmir 5,000		Baroda 3,700		All India—3,400,000-(Varified area—2,325,750)	
Deccan 60,200		South 24,300		Gujerat 4,200																			
Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
...	...	...	...	3,150	75·0	...	...	4,662	10·0	1,200	3·0	31,100	89·0	...	...	3,100	35·0	...	...	470	13·0	386,000	16·6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,800	20·0	700	15·0	...	...	246,900	10·6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	500	10·0	...	...	200,000	8·6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2,500	50·0	...	...	183,000	7·7
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	400	5·0	...	...	...	...	175,000	7·5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	5,200	17·0	...	...	...	...	...	...	165,000	7·1
...	...	...	...	...	...	...	...	8,842	19·0	...	...	...	...	...	...	...	...	...	...	...	...	132,000	5·7
10,989	18·0	18,434	75·0	420	10·0	20,766	40·0	21,000	45·0	26,000	65·0	...	...	5,200	17·0	...	...	...	...	370	10·0	128,000	5·5
19,264	32·0	2,430	10·0	...	...	...	...	11,872	25·0	12,500	31·0	...	...	6,800	22·0	...	...	...	...	2,570	69·0	117,500	5·1
...	...	...	...	...	...	6,000	11·0	...	...	...	...	...	...	...	...	...	...	1,000	20·0	...	...	115,000	4·9
30,100	50·0	...	...	...	...	...	...	...	...	400	1·0	...	...	...	...	...	...	...	...	...	...	67,600	2·9
...	...	...	...	...	...	...	...	...	...	...	...	2,800	8·0	...	...	1,300	15·0	...	...	...	...	65,000	2·8
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	57,000	2·5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	46,300	2·0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	38,000	1·6
...	...	...	...	...	...	23,265	44·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	23,500	1·0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20,000	0·9
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19,500	0·8
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	14,700	0·6
...	...	3,400	15·0	630	15·0	2,600	5·0	...	...	...	...	1,000	3·0	13,700	44·0	2,400	25·0	300	5·0	300	8·0	143,000	6·0

IMPROVED RICE STRAINS IN THE CENTRAL PROVINCES

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(Received for publication on 13 July 1942)

(With Plate XX)

HE paramount importance in the Central Pro- nces and Berar of the rice crop which occupies 872,759 acres out of a total of 24,545,668 acres nder crops requires but little emphasis. The rcentages which the areas under principal crops ar to the total cropped area are given below :

	Per cent
Rice	23·92
Jowar and *jowar-arhar*	19·02
Cotton and cotton-*arhar*	14·97
Wheat and wheat-gram	14·15

The areas where rice is largely grown fall into ree tracts. The first lies in the east of the pro- nce in the Mahanadi basin and includes the stricts of Raipur, Drug and Bilaspur in the hhattisgarh division. The common method of ltivation here is known as *biasi*§ and the greater rt of the crop is unirrigated. The second tract es in the Wainganga valley running from Seoni to handa and includes the southern parts of Seoni, e low areas of Balaghat and the eastern portions f Bhandara and Chanda. This tract grows some the finest varieties of the province. Most of the op here is raised from transplanted seedlings d a large proportion is irrigated. The third tract situated in the north of the province and includes e districts of Jubbulpore and Mandla and the uthern parts of Damoh. In this tract rice is sually sown broadcast and the crop is rarely irri- ated. The area under rice in the important rice rowing districts and the percentage under irri- ation is shown in Table I.

TABLE I

rea under rice in the important rice growing districts in the Central Provinces (1940-41)

District	Area under crops (' 000 acres)	Area under rice (' 000 acres)	Percentage under rice	Percentage of rice area irrigated
aipur	1,957	1,555	79·5	23
alaghat	568	440	77·4	41
ilaspur	1,741	1,312	75·4	22
handara	835	538	64·4	51
rug	1,510	804	53·8	28
handa	1,009	832	32·9	56
'andla	721	178	24·7	*Nil*
ubbulpore	971	230	23·7	7
eoni	724	133	18·4	25
amoh	526	84	16·1	5

§*Biasi*—a method of rice cultivation in which seed is sown broad- ast followed by ploughing to thin out the seedlings when they are a ot high

The annual production of rice (not in husk) is estimated at 451* lakhs of maunds and at the lowest rate of Rs. 2-8 per maund** is valued at over 11 crores of rupees. It is obvious that even a 10 per cent improvement in yield would mean an enormous gain to the vast number of peasants engaged in its cultivation. Some of the new strains evolved by selection or hybridization have given much higher yield than 10 per cent. For example, the strain R 7-*Ajan* has given, on an average of five years, an increased yield of 27 per cent over *Gurmatia* which is the standard late variety in Chhattisgarh. The results of these experiments are summarized below.

This work formed part of the programme of the Central Provinces Rice Research Scheme which has been generously financed by the Imperial Council of Agricultural Research.

Experimental results

In the improvement of any crop, the first step usually consists in making a collection of as many varieties as possible with a view to raising pure lines. In December 1932, a collection of 1299 samples of paddy from different parts of the province was made. A close examination of the samples revealed that in the majority of cases the crop grown at present consists of a mixture of different varieties. The percentage of mixture in the samples, considering only the colour of lemma and palea and the size and colour of rice, is given in Table II.

The results of the analysis show that the crop grown at present usually contains 22 per cent mixture of other varieties which would naturally differ in their cropping power. The mixture of red rice alone is about 9 per cent. Rice with a red pericarp in a white sample is disliked by the trade while a mixture of grains of uneven size in the produce causes breakage in milling.

The main problem for the improvement of this crop, therefore, was the purification and comparative testing of varieties and the selection of high-yielding strains from the promising ones.

*Average of five years, 1934 to 1938

** Pre-war price

The exports of rice (not in husk) amount to about 50 lakhs of maunds and the imports one lakh maunds

TABLE II

Percentage of mixture in rice varieties collected during 1932-33

Tahsil	No. of samples collected	Average percentage of total mixture	Average percentage of red rice
Raipur	51	12·1	7·4
Balodabazar	68	14·9	6·4
Dhamtari	32	15·1	9·1
Mahasamund	79	26·3	9·6
Balaghat	50	27·6	8·3
Waraseoni	70	16·7	5·0
Bilaspur	90	9·6	4·0
Mungeli	71	20·4	9·2
Janjgir	43	5·1	1·4
Katghora	13	12·9	8·8
Gondia	50	17·1	6·2
Jubbulpore	23	19·9	7·3
Sihora	38	33·9	13·2
Murwara	24	47·6	22·7
Patan	8	13·0	6·7
Seoni	16	30·7	12·1
Lakhnadon	15	26·1	10·0
Damoh	18	25·0	7·0
Hatta	5	19·0	11·6
Khandwa	7	26·5	22·3
Burhanpur	1	26·0	9·4
Harsud	4	23·2	13·6
Drug	100	20·3	7·6
Sanjaribalod	59	13·0	6·8
Bemetara	20	13·4	7·3
Chanda	33	10·1	5·2
Brahmpuri	36	28·9	10·9
Garhchiroli	56	14·6	5·0
Saugor	2	62·1	21·5
Banda	16	36·4	20·9
Nagpur	22	18·2	5·2
Umrer	9	19·9	2·6
Hoshangabad	7	20·0	8·0
Harda	2	7·3	5·6
Sohagpur	9	37·8	17·6
Average		22	9

The varieties of rice recommended by the Department of Agriculture, Central Provinces, when this work was started are given below.

	Chhattisgarh	Wainganga valley	North of the Province
Early	..	No. 17	No. 17
	Bhatagurmatia	*Bhatagurmatia*	..
Medium	*Surmatia*	..	*Chhatri*
	Ludko	..	..
	Bhondu	*Bhondu*	..
	Parewa	..	..
Late	*Gurmatia*	..	*Dilbuksha*
	Luchai	*Luchai*	..
	Chinoor (long)	*Chinoor* (long)	..

Varieties from the new collection which were duplicates of those mentioned above and also others possessing red rice or bad texture of endosperm were rejected and the remaining samples, from which mixture of other seed had been removed, were grown during 1933, in single lines 1 ft. apart with 6 in. spacing between individual plants. The experiments were repeated in three different fields. A study of the morphological characters was made and varieties which were obviously unfit for further work due to poor growth or other undesirable characters were rejected. Plants not true to type in each variety were also eliminated before harvest. When ripe, ears from each plant were harvested separately and examined in the laboratory for colour of lemma and palea, size and colour of rice and texture of endosperm. A large number of typical good plants were selected from each variety and reasonably pure bulk seed was obtained for preliminary yield trials in succeeding years so that promising varieties may be isolated which could be further improved by pure line selection.

Simultaneously, single plant selection for high yield was started in varieties commonly grown by the cultivator and also in those which appeared promising in the preliminary yield trials. The commercial varieties such as *Chhatri*, *Banspatri*, *Kubrimohar*, etc. were found to contain strains differing in the time of ripening, size of grain and cropping power. They also contained a large amount of red rice. Seed of the same variety from different places was mixed and grown in a uniform field of about half an acre with 6 in. spacing between individual plants. Observations on growth and time of flowering were made and at the ripening stage about a thousand best typical plants were selected in the field. When ripe, ears from each plant were harvested separately and examined in the laboratory for colour of grain and rice, texture of endosperm and yield. About 200 best plants were selected for propagating the progeny of each separately in the succeeding year.

In the second year, the single plant selections were grown in small plots $4\frac{1}{2}$ ft. $\times$ $4\frac{1}{2}$ ft. with 6 in. spacing between plants and 1 ft. between adjacent plots. For comparison one plot of unselected variety was introduced after every three cultures. A study of their morphological characters was made and cultures which showed splitting or were inferior in vigour were eliminated before harvest. The yield of each plot was recorded after rejecting two rows of border plants and a few selections were discarded on the basis of yield. About 50 best selections were retained for comparative yield trials.

The comparative yield trials were started in the third year. The selections were grown in plots $4\frac{1}{2}$ ft. $\times 4\frac{1}{2}$ ft. with 6 in. spacing between individual plants and the number of replications was six. In every group of 10 cultures a plot of unselected variety was included to act as control. The best 15 cultures were retained which were again tested for yield, in the fourth year, in randomized blocks with six replications. The plots were $4\frac{1}{2}$ ft. $\times 10$ ft. containing 210 plants spaced 6 in. apart and the best five strains were selected.

These five strains were then tested at different centres in 1/100 or 1/200 acre plots with six replications and the most promising strain was isolated in the course of the next two or three years. This strain was finally multiplied for distribution.

The preliminary yield trials with 551 new varieties were started at Raipur in 1934. Varieties similar in time of ripening and size of kernels were included in one test and one of the Departmental varieties was used for comparison. The plots were $3\frac{1}{2}$ ft. × 10 ft. with 6 in. spacing between individual plants and the number of replications was five. 356 varieties were selected which were similarly tested for yield during 1935.

For the isolation of high yielding varieties suitable for the Wainganga valley and the north of the province, replicated yield trials were started in 1935, at Waraseoni and Jubbulpore.

In 1936 the number of varieties under preliminary yield trials at Raipur was brought down to 123. They were tested in plots 4 ft. × 11 ft. containing 207 plant spaced 6 in. apart and the number of replications was 10. The maximum numbers of varieties in a single test was 12. Fifty-one promising varieties were selected.

Regular yield trials with strains raised from single plant selections of promising varieties were started at Raipur, Waraseoni and Jubbulpore in 1937 and were continued for five years. The experiments were laid out in randomized blocks with six replications and the plots were either 1/100th or 1/200th of an acre. The results are summarized in Table III.

Sixteen highest-yielding strains of early, medium and late rices have now been isolated.

List of improved rice strains

(Recommended by the Department of Agriculture, Central Provinces)

	Chhattisgarh	Wainganga Valley	North of the Province
	Strains of medium and coarse varieties		
Early	R 2 *Nungi* (No. 17)	R 2 *Nungi* (No. 17)	R 2 *Nungi* (No. 17)
	R 3 *Sultugurmatia**	R 3 *Sultugurmatia*	R 3 *Sultugurmatia*
Medium	R 4 *Surmatia*	..	..
	R 5 *Ludko*	..	..
	Cross No. 116* (*Bhondu X Parewa*)	Cross No. 22 (*Bhondu X Parewa*)	Cross No. 22 (*Bhondu X Parewa*)
Late	Cross No. 19* (*Budhiabako X Parewa*)	..	..
	R 6 *Budhiabako**	R 6 *Budhiabako*	R 6 *Budhiabako*
	R 7 *Ajan**	..	..
	R 8 *Benisar**	R 8 *Benisar*	..
	R 8 *Luchai*	R 8 *Luchai*	..
	Strains of fine, scented varieties		
Medium	R 10 *Chhatri**	R 10 *Chhatri*	R 10 *Chhatri*
	R 11 *Dubraj**	..	..
	R 12 *Banspatri**	R 12 *Banspatri*	R 12 *Banspatri*
Late	R 13 *Kubrimohar**	..	..
	R 14 *Badshahbhog**	..	R 14 *Badshahbhog*
Very late	R 15 *Chinoor** (short)	R 15 *Chinoor* (short)	..

The newly evolved improved strains * were simultaneously tested on an extensive scale on private seed farms and in 1941-42 they were multiplied in 24,000 acres in Chhattisgarh. 'Yield trials in cultivators' fields show that these strains give an increased outturn of at least 10 per cent over ordinary varieties, the average value of which will not be less than Rs. 3 per acre.' The best of the new strains, however, outyield the older varieties by over 27 per cent.

It is expected that a scheme for the extension of the area under improved rice strains in the Central Provinces, costing about Rs. 53,900, will commence in 1943 so that at the end of two years, one out of every two villages in 16 important tahsils of the main rice-producing districts shall be growing at least 50 acres under improved rice strains. Further expansion can then be left to natural spread.

A description of the improved rice strains is given below and in Tables IV and V.

Description of improved rice strains§

Strains of medium and coarse varieties

R 2 *Nungi* (No. 17). A high-yielding early strain suitable for unprotected high lying areas and

* Plate XX

§ General yields during 1940 and 1941 are low on account of inadequate rains

TABLE III

Improved rice strains in the Central Provinces

(Average yield in lb. per acre, 1937 to 1941)

Strains	Time of ripening (Sowing time-middle of June)	Size of kernels	Chhattisgarh Raipur	Unmanured					Wainganga valley Waraseoni						North of the Province Jubbulpore					
			1937	1938	1939	1940	1941	Average	1937	1938	1939	1940	1941	Average	1937	1938	1939	1940	1941	Average
								Strains of medium and coarse varieties												
R 2 *Nungi* (No. 17)	Oct. 3rd week	Medium	2223	1405	1294	550	1046	1304	1138	2558	1476	2244	583	1600	2766	2414	976	886	1351	1679
R 3 *Sultugurmatia*	Oct. 4th week	Medium	1991	..	1548	1338	1644	1630	2438	2638	2550	2838	792	2251	2944	2646	2250	730	1786	2071
R 4 *Surmatia*	Nov. 1st week	Medium	1628	1495	1528	1430	1421	1501	..	..	..	..	..	..	..	..	..	..	..	..
R 5 *Ludko*	Nov. 2nd week	Medium	2266	1232	1688	1640	1354	1636	..	..	..	..	..	..	..	..	..	..	..	..
Cross No. 116 (*Bhondu* × *Parewa*)	Nov. 2nd week	Coarse	3061	1756	1807	1686	1627	1987	..	3084	2876	2688	2100	2687*	..	2906	3083	1090	2352	2358*
Cross No. 19 (*Budhiabako* × *Parewa*)	Nov. 3rd week	Medium-fine	2932	1572	1497	1461	1323	1757	..	..	..	..	..	..	..	..	..	..	..	..
R 6 *Budhiabako*	Nov. 3rd week	Medium-fine	2527	1603	1411	1175	1375	1618	1784	2312	2426	2588	1125	2047	2246	3052	2557	1180	2207	2248
R 7 *Ajan*	Nov. 3rd week	Medium	2749	1667	1871	1640	1432	1872	..	..	..	..	..	..	..	..	..	..	..	..
Gurmatia (Control)	Nov. 3rd week	Medium	2419	976	1582	992	1388	1471	..	..	..	..	..	..	..	..	..	..	..	..
R 8 *Benisar*	Nov. 4th week	Medium	2594	2075	1655	1403	1313	1808	2300	3042	2126	2814	1046	2266	..	..	..	..	..	..
R 8 *Luchai*	Nov. 4th week	Short, medium	2599	1621	1761	1218	1192	1678	1742	3176	2076	2656	1608	2252	..	..	..	..	..	..
								Strains of fine scented varieties												
R 10 *Chhatri*	Nov. 1st week	Medium, fine	1632	1315	1228	958	1100	1247	1878	1222	1050	1300	1229	1336	1922	..	1300	492	1198	1228
R 11 *Dubraj*	Nov. 2nd week	Short, fine	1860	1494	1195	1180	1159	1378	..	..	..		..	..	..	..	..	..	..	..
R 12 *Banspatri*	Nov. 2nd week	Medium, fine	1913	1484	1511	1287	1311	1501	2408	2222	1926	2250	1846	2130	1918	2308	2008	638	986	1572
R 13 *Kubrimohar*	Nov. 3rd week	Short, fine	1707	1647	1526	1458	1569	1581	..	..	..	..	..	..	..	..	..	..	..	..
R 14 *Badshahbhog*	Nov. 4th week	Very short, fine	1547	1652	1381	1142	1292	1403	..	..	..	..	..	..	..	..	2108	518	1050	1225
R 15 *Chinoor*	Dec. 1st week	Short, fine	2432	1668	1423	1158	1165	1569	..	2388	1450	2500	1250	1897	..	..	..	..	..	..

*Cross No. 22 (*Bhondu* × *Parewa*)

General yields during 1940 and 1941 are low on account of inadequate rains

unirrigated tracts. Ripens in the 3rd week of October (sowing time—middle of June). Paddy, straw coloured with black spots. Rice, medium in size. Average yield, 1937 to 1941 (unmanured) 1,300 lb. per acre.

R 3 *Sultugurmatia*. This is the highest-yielding strain among early varieties. It ripens in the 4th week of October and may be grown without irrigation. Leaf-sheath dark purple. Paddy, straw-coloured with black spots. Rice, medium in size. Average yield, 1937 to 1941 (unmanured) 1,630 lb. per acre.

R 4 *Surmatia*. A medium-ripening strain which can be grown in lighter soils partially protected by irrigation. Ripens in the 1st week of November. Leaf-sheath dark purple. Paddy, straw coloured with purple spreading from the tip of the grain. Rice, medium in size and translucent. Average yield, 1937 to 1941 (unmanured) 1,500 lb. per acre.

R 5 *Ludko*. A medium-ripening strain grown in irrigated fields. It also does well on heavier soils where it can be followed by a second crop (*Utera*). Ripens in the second week of November. Leaf-sheath green. Paddy with brown furrows. Rice, medium in size. Average yield, 1937 to 1941 (unmanured) 1,640 lb. per acre.

Cross No. 116 (*Bhondu*×*Parewa*). This is the highest-yielding strain in the province and is much liked by people who prefer bulk to quality. It ripens in the 2nd week of November and is suitable for all types of soils protected by irrigation. It has dark purple auricles to distinguish it from wild rice (*Karga*). The paddy is reddish brown and the rice is coarse and white suitable for the preparation of puffed and shredded rice. Endosperm, abdominal white. Average yield, 1937 to 1941 (unmanured) 1,990 lb. per acre. It gives 10 per cent higher yield than *Bhondu* which was so far the most prolific variety.

Cross No. 19 (*Budhiabako*×*Parewa*). This is the highest-yielding strain among medium-fine varieties and is well suited for irrigated tracts. It has dark purple auricles to distinguish it from wild rice. It is late and is harvested in the 3rd week of November. It has become very popular in Chhattisgarh under the name *Kanthi Budhiabako*. Average yield, 1937 to 1941 (unmanured) 1,760 lb. per acre.

R 6 *Budhiabako*. A high-yielding late strain well suited for irrigated tracts. Ripens in the 3rd week of November. Leaf-sheath green. Paddy, straw-coloured. Rice, medium-fine, translucent and much in demand in the market under the trade name *Hansa*. Gives a high percentage of whole rice in milling and resists drought better than other varieties. Average yield, 1937 to 1941 (unmanured) 1,620 lb. per acre.

R 7 *Ajan*. A late strain suitable for irrigated tracts. It has given, on an average of five years, an increased yield of 27 per cent over *Gurmatia* which is the standard late variety in Chhattisgarh. Can safely replace *Gurmatia*. Ripens in the 3rd week of November. Leaf-sheath dark purple. Paddy, straw-coloured with black spots. Rice, medium in size. Average yield, 1937 to 1941 (unmanured) 1,870 lb. per acre.

R 8 *Benisar*. A high yielding late strain which ripens in the 4th week of November and is suitable for irrigated tracts. Can also be grown in heavy soils and low lying areas. Auricles, purple. Paddy, straw-coloured. Rice, medium in size. Average yield, 1937 to 1941 (unmanured) 1,810 lb. per acre.

R 8 *Luchai*. A high yielding late strain with erect growth and comparatively free from lodging. Grows well in heavy soils and low lying areas. Ripens in the 4th week of November. Paddy, light-gold in colour. Rice, short abdominal white. It gives a high percentage of breakage in milling and is, therefore, more suitable for the preparation of par-boiled rice. Average yield, 1937 to 1941 (unmanured) 1,680 lb. per acre.

Strains of fine, scented varieties

R 10 *Chhatri*. This is the earliest among fine, scented varieties. It ripens in the 1st week of November and can be grown in fields partially protected by irrigation. Paddy, straw-coloured with brown spreading from the tip of the grain. Outer glumes, brown. Rice, good translucent, fine and scented. Gives a high percentage of whole rice in milling. Average yield, 1937 to 1941 (unmanured) 1,250 lb. per acre.

R 11 *Dubraj*. A medium ripening strain known for its cooking quality. The cooked rice is very soft to the touch. Ripens in the 2nd week of November. Grains, straw-coloured with awns. Rice, fine, scented and translucent. Average yield, 1937 to 1941 (unmanured) 1,380 lb. per acre.

R 12 *Banspatri*. The highest yielding strain among medium maturing varieties of fine quality. Ripens in the 2nd week of November. Paddy, straw-coloured with purple spreading from the tip of the grain. Outer glumes, purple. Rice, fine, scented and translucent. Average yield, 1937 to 1941 (unmanured) 1,500 lb. per acre.

R 13 *Kubrimohar*. A high yielding late strain which ripens in the 3rd week of November and is grown in irrigated fields. It does not shed its grain readily. Paddy, rich brown with yellow colour varying in distribution along the ridges. Rice, short, fine, slightly curved and scented. Average yield, 1937 to 1941 (unmanured) 1,580 lb. per acre.

TABLE

Improved rice strains in the Central Provinces—

(Rice Research

Strains	Coleoptile	Leaf sheath	Sheath axil	Internode	Leaf-junctura	Auricle	Ligule	Pulvinus	Septum	Leaf blade
										Strains of medium
R 2 *Nungi* (No. 17)	Purp.	L. Purp. (7) (P-L. purp. V-L. purp.)	Purp. (P-Purp. V-Purp.)	L. Purp. lines (3).	L. gr. .	L. gr.	Wh. .	Gr. purp. spots	Cream, purp. spots	Gr. .
R 3 *Sultugurmatia*	Dark purp.	D. purp. (8) (P-D. purp. V-Purp.)	D. purp. (P-Purp. V-D. purp.)	L. purp. lines (3)	L. gr. purp. spots.	L. gr. purp. spots	Wh. margin purp.	Gr. purp. spots.	L. Purp.	Gr. (1) margin purp.
R 4 *Surmatia* .	Gr.	D. purp. (8) (P-D. purp. V-Purp.)	Wh. . .	L. gr. (1) .	L. gr. purp. spots.	L. gr. purp. spots.	Wh. margin purp.	Gr. .	Purp.	Gr. (2) margin purp.
R 5 *Ludko* . .	Gr.	Green (1) .	Wh. . .	L. gr. (1) .	L. gr.	L. gr. .	Wh. .	Gr. .	Cream	Gr.
Cross No. 116 . (*Bhondu X Parewa*)	Purp.	L. purp. (7) (P-L. purp. V-L. purp.)	Purp. (P-Purp. V-Purp.)	L. yell. (2)	Dark purp.	Dark purp.	Wh. . .	Dark purp.	Brown	Gr., broad
Cross No. 19 (*Budhiabako X Parewa*)	Purp.	L. purp. (7) (P-L. purp. V-L. purp.)	Purp. (P-Purp. V-Purp.)	L. gr. (1) .	Dark purp.	Dark purp.	Wh. .	Dark purp.	Purp.	Gr.
R 6 *Budhiabako* .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr.	Cream	Gr. .
R 7 *Ajan* . .	D. purp.	D. purp. (8) (P-D. purp. V-Purp.)	D. purp. (P-D. purp. V-Purp.)	Purp. (7) .	L. gr. purp. spots	L. gr. purp. spots	Purp. lines	Gr. purp. spots	Purp.	Gr. (1) margin purp.
R 8 *Benisar* .	D. purp.	Gr. (False colour)	D. Purp. (P-D. Purp. V-D. purp.)	L. gr. (1)	Purp. .	Purp. .	Wh. .	Purp. .	Purp.	Gr. .
R 8 *Luchai* . .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. . .	Cream	Gr. .
										Strains of fine,
R 10 *Chhatri* .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. .	Purp. centre	Gr. .
R 11 *Dubraj* .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. .	Cream	Gr. .
R 12 *Banspatri* .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. .	Dark purp.	Gr. (1) margin purp.
R 13 *Kubrimohar* .	Gr.	Gr. (1) .	Wh. . .	L. yell. (2)	L. gr. .	L. gr. .	Wh. .	Gr. .	Cream	Gr. .
R 14 *Badshahbhog*	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. .	L. brown	Gr. .
R 15 *Chinoor* .	Gr.	Gr. (1) .	Wh. . .	L. gr. (1) .	L. gr. .	L. gr. .	Wh. .	Gr. .	Cream	Gr. .

(A, D, 1, 7 etc. refer to coloured plates in " Description of crop plant characters

IV

Description of morphological characters

Station, Raipur)

Glumes (early stage)	Glumes (ripe stage)	Lemma and palea (early stage)	Lemma and palea (ripe stage)	Apiculus	Stigma	Awns	Habit	Straw	Panicle	Rice size	Rice colour	Rice scent	Rice endosperm
and coarse varieties													
Wh.	Wh.	L. gr. (D) black spots	Straw, black spots (d)	Purp. (G)	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium	Wh.	Abs.	Mostly trans
Wh.	Wh.	L. gr. (D) black spots	Straw, black spots (d)	D. purp. (G)	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium	Wh.	Abs.	Trans. and abd. wh.
Purp.	Purp.	L. gr. (J)	Straw (j)	Spr. purp. (J)	Wh.	Abs.	Spr.	Weak	Ex. Com. Droop	Medium	Wh.	Abs.	Trans.
Wh.	Wh.	Dark furrows (C)	Brown furrows (c)	Not col.	Wh.	Abs.	Spr.	Weak	Ex. Com. Droop	Medium	Wh.	Abs.	Trans. and abd. wh.
Wh.	Wh.	Reddish orange (M)	Reddish brown (m)	Spr. purp.	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Coarse	Wh.	Abs.	Abd. wh.
Wh.	Wh.	L. gr. (F)	Straw (f)	L. purp. (F)	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium fine	Wh.	Abs.	Trans. and abd. wh.
Wh.	Wh.	L. gr. (A)	Straw (a-1)	Not col.	Wh.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium fine	Wh.	Abs.	Mostly trans.
Wh.	Wh.	L. gr. (D) black spots	Straw, black spots (d)	D. purp. (G).	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium	Wh.	Abs.	Mostly trans.
Wh.	Wh.	L. gr. (F)	Straw (f)	Purp. (F)	D. purp.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium	Wh.	Abs.	Trans. and abd. wh.
Wh.	Wh.	L. yell.	Light gold	Not col.	Wh.	Abs.	Erect	Strong	W. ex. Com. Droop	Short, medium	Wh.	Abs.	Mostly abd. wh.
scented varieties													
Wh.	Brown	L. gr.	Straw	Spr. brown	Wh.	Abs.	Spr.	Weak	W. ex. Com. Droop	Medium, fine	Wh.	Pre.	Good trans.
Wh.	Wh.	L. gr. (A)	Straw (a-1)	Not col.	Wh.	Awned. wh.	Spr.	Weak	W. ex. Com. Droop	Short, fine	Wh.	Pre.	Trans.
D. purp.	Purp.	L. gr. purp. spr. (J)	Straw (j)	Spr. purp. (J)	Wh.	Tips. purp.	Spr.	Weak	W. ex. Com. Droop	Medium, fine	Wh.	Pre.	Trans.
Wh.	Brown	L. gold furrow	Rich br. ridges yellow	Brown	Wh.	Abs.	Spr.	Weak	W. ex. Com. Droop	Short, fine	Wh.	Pre.	Mostly trans.
Wh.	Brown	L. gold (A)	Rich brown (a-3)	L. brown	Wh.	Abs.	Spr.	Weak	W. ex. Com. Droop	V. short, fine	Wh.	Pre.	Trans. and abd. wh.
Wh.	Wh.	L. gr. (A)	Straw (a-1)	Not col.	Wh.	Tips wh.	Spr.	Weak	W. ex. Com. Droop	Short, fine	Wh.	Pre.	Trans.

and their ranges of variation, Rice," (*Indian J. agric. Sci.* 8, 567—Oct. 1938)

TABLE

Improved rice strains in

Description of quan-

(Average of three

(Rice Research

Strains	Height of plants in cm.	No. of tillers per plant	Flowering date—Days from sowing to flowering	Ripening date—Days from sowing to ripening	Length of panicle in cm.	No. of grains per panicle	Sterility percentage
							Strains of medium
R 2 *Nungi* (No. 17)	98·6 ±2·635	1·73 ±0·114	21 Sept. 98±0·402	16 Oct. 123±0·342	22·9 ±0·66	121·1 ±8·18	8·3 ±2·043
R 3 *Sultugurmatia*	93·0 ±1·448	1·99 ±0·145	26 Sept. 103±0·501	24 Oct. 131±0·619	22·0 ±0·353	96·6 ±4·711	7·2 ±1·396
R 4 *Surmatia*	94·6 ±1·562	1·67 ±0·157	10 Oct. 117±0·420	6 Nov. 144±0·408	21·3 ±0·434	117·7 ±6·385	9·9 ±1·490
R 5 *Ludko*	102·7 ±2·17	1·57 ±0·108	12 Oct. 119±0·308	10 Nov. 148±0·577	20·7 ±0·530	138·7 ±9·76	12·5 ±2·367
Cross No. 116 (*Bhondu X Parewa*)	111·3 ±1·451	1·73 ±0·149	13 Oct. 120·±0·325	10 Nov. 148±0·707	21·3 ±0·63	103·7 ±5·72	14·30 ±1·890
Cross No. 19 (*Budhiabako X Parewa*)	115·4 ±1·906	2·17 ±0·195	15 Oct. 122±0·349	16 Nov. 154±0·224	22·18 ±0·471	115·7 ±6·67	13·73 ±1·745
R 6 *Budhiabako*	105·97 ±1·288	1·93 ±0·152	16 Oct. 123±0·253	17 Nov. 155±0·466	22·8 ±0·410	139·5 ±6·411	15·3 ±1·519
R 7 *Ajan*	100·4 ±1·66	2·06 ±0·186	18 Oct. 125±0·288	17 Nov. 155±0·619	20·6 ±0·521	115·7 ±8·169	8·4 ±1·592
R 8 *Benisar*	110·7 ±1·539	2·40 ±0·201	27 Oct. 134±0·313	28 Nov. 166±0·408	19·2 ±0·398	131·3 ±9·681	9·8 ±1·569
R 8 *Luchai*	108·5 ±1·366	1·99 ±0·153	25 Oct. 132±0·272	25 Nov. 163±0·224	18·8 ±0·341	179·1 ±13·11	12·2 ±1·481
							Strains of fine,
R 10 *Chhatri*	110·5 ±1·730	1·84 ±0·151	8 Oct. 115±0·325	7 Nov. 145±0·500	24·9 ±0·542	128·2 ±6·972	16·3 ±2·641
R 11 *Dubraj*	108·9 ±1·332	2·71 ±0·179	13 Oct. 120±0·283	9 Nov. 147±0·671	25·5 ±0·553	117·6 ±8·684	12·7 ±2·017
R 12 *Banspatri*	116·0 ±1·253	2·05 ±0·198	13 Oct. 120±0·393	12 Nov. 150±0·577	24·9 ±0·510	138·5 ±12·00	5·0 ±1·344
R 13 *Kubrimohar*	122·4 ±2·154	2·61 ±0·229	18 Oct. 125±0·267	19 Nov. 157±0·913	24·07 ±0·646	145·4 ±9·688	12·7 ±1·760
R 14 *Badshahbhog*	122·7 ±2·713	2·93 ±0·27	21 Oct. 128±0·389	24 Nov. 162±0·258	25·2 ±0·748	200·7 ±15·77	12·9 ±1·647
R 15 *Chinoor*	116·4 ±1·582	2·59 ±0·156	26 Oct. 133±0·429	1 Dec. 169±0·408	23·67 ±0·590	130·3 ±11·30	13·0 ±2·360

General yields during 1940 and 1941

V

the Central Provinces—

titative Characters

years, 1939 to 1941)

Station, Raipur)

Grain			Rice			Weight of 1000 grains in gm.	Weight of 1000 kernels in gm.	Yield per plant in gm.	Milling quality		
Length mm.	Breadth mm.	L/B Ratio	Length mm.	Breadth mm.	L/B Ratio				Whole rice per cent	Broken rice per cent	Husk and bran per cent
and coarse varieties											
8·35 ±0·038	3·05 ±0·020	2·80 ±0·018	6·05 ±0·048	2·44 ±0·009	2·49 ±0·013	24·1 ±0·029	17·1 ±0·045	3·57 ±0·212	46·70 ±3·154	21·13 ±2·855	32·17 ±1·212
8·12 ±0·039	2·87 ±0·037	2·80 ±0·014	5·87 ±0·042	2·41 ±0·013	2·44 ±0·011	23·7 ±0·021	17·6 ±0·021	4·18 ±0·31	46·63 ±1·353	22·10 ±1·086	31·27 ±0·806
8·57 ±0·049	2·98 ±0·014	2·87 ±0·015	6·19 ±0·027	2·51 ±0·009	2·46 ±0·012	26·2 ±0·057	19·8 ±0·037	5·16 ±0·26	49·60 ±3·705	20·73 ±3·55	29·67 ±1·175
8·21 ±0·065	2·86 ±0·016	2·87 ±0·049	5·97 ±0·02	2·39 ±0·01	2·50 ±0·019	21·8 ±0·079	16·9 ±0·032	5·10 ±0·32	50·20 ±2·573	17·67 ±2·784	32·13 ±0·854
8·29 ±0·038	3·37 ±0·013	2·46 ±0·016	5·89 ±0·030	2·86 ±0·013	2·06 ±0·016	29·1 ±0·044	22·4 ±0·039	5·17 ±0·31	42·94 ±1·648	26·13 ±1·176	30·93 ±0·532
9·22 ±0·039	2·47 ±0·009	3·74 ±0·020	6·50 ±0·065	2·03 ±0·008	3·20 ±0·047	19·97 ±0·086	14·86 ±0·047	4·35 ±0·204	50·67 ±1·915	15·93 ±2·662	33·40 ±1·245
9·33 ±0·069	2·47 ±0·010	3·79 ±0·019	6·33 ±0·033	2·04 ±0·040	3·14 ±0·022	19·4 ±0·047	14·5 ±0·036	4·23 ±0·165	54·33 ±0·469	13·17 ±0·794	32·5 ±0·849
8·53 ±0·052	2·95 ±0·012	2·89 ±0·018	6·08 ±0·029	2·40 ±0·012	2·52 ±0·022	24·1 ±0·044	17·5 ±0·025	3·65 ±0·350	51·70 ±4·637	15·90 ±4·441	32·40 ±0·721
8·02 ±0·031	2·54 ±0·015	3·17 ±0·045	5·82 ±0·025	2·09 ±0·035	2·79 ±0·023	18·7 ±0·063	14·0 ±0·043	5·05 ±0·341	49·37 ±5·067	18·97 ±4·762	31·66 ±0·346
7·72 ±0·037	2·59 ±0·013	2·99 ±0·019	5·65 ±0·025	2·16 ±0·033	2·62 ±0·017	17·9 ±0·034	13·1 ±0·043	4·79 ±0·386	41·70 ±7·746	24·53 ±7·535	33·77 ±2·09
scented varieties											
8·32 ±0·046	2·38 ±0·018	3·50 ±0·026	6·09 ±0·054	1·99 ±0·010	3·06 ±0·024	17·5 ±0·056	13·8 ±0·077	4·08 ±0·230	54·27 ±2·474	14·47 ±2·823	31·26 ±1·217
7·97 ±0·052	2·31 ±0·020	3·45 ±0·039	5·86 ±0·038	1·91 ±0·010	3·07 ±0·030	15·58 ±0·025	11·81 ±0·018	3·62 ±0·207	45·1 ±0·158	23·1 ±0·387	31·8 ±0·671
8·33 ±0·039	2·37 ±0·053	3·52 ±0·029	6·06 ±0·045	1·98 ±0·017	3·08 ±0·043	16·91 ±0·041	12·89 ±0·024	4·79 ±0·221	48·07 ±3·575	20·17 ±5·068	31·76 ±1·587
7·41 ±0·040	2·43 ±0·015	3·05 ±0·038	5·49 ±0·038	2·03 ±0·014	2·70 ±0·023	13·87 ±0·034	11·03 ±0·021	4·22 ±0·277	42·33 ±2·748	23·07 ±3·041	34·60 ±0·529
6·00 ±0·044	2·20 ±0·043	2·73 ±0·031	4·35 ±0·035	1·88 ±0·009	2·31 ±0·015	9·43 ±0·038	7·70 ±0·034	3·75 ±0·58	53·70 ±2·646	18·37 ±2·546	27·93 ±1·285
7·71 ±0·050	2·30 ±0·030	3·49 ±0·025	5·71 ±0·034	1·88 ±0·027	3·04 ±0·031	14·95 ±0·056	11·53 ±0·051	4·11 ±0·296	55·80 ±3·606	14·63 ±3·659	29·57 ±0·224

are low on account of inadequate rains

R 14 *Badshahbhog*. A late strain known for its very short rice which is highly scented. Ripens in the 4th week of November. Paddy of attractive rich brown colour. Average yield, 1937 to 1941 (unmanured) 1,400 lb. per acre.

R 15 *Chinoor*. A very late strain which is harvested in the beginning of December and can be grown only where irrigation is assured. It is reckoned to be the finest variety in the province and fetches a high premium in the market. It does not shed its grain and mills well. The grain is straw coloured with very short awns. The rice is short, fine, scented and translucent. Average yield, 1937 to 1941 (unmanured) 1,570 lb. per acre.

Summary

The work of breeding high yielding strains suitable for the main rice tracts of the Central Provinces has been in progress for the last nine years. "Excellent results have been obtained by selection from among existing varieties and hybrids of economic value have been bred. The research station has produced 10 selections and two hybrids, all of which will be of definite economic value to one or more of the rice tracts of the province. The 12 new strains include early, medium and late maturing rices. Yield trials in cultivators' fields show that these strains give an increased outturn of at least 10 per cent over ordinary varieties, the average value of which will not be less than Rs. 3 per acre [McDougall, 1941]. The best of the new strains, however, out yield the older varieties by about 27 per cent. A description of the improved rice strains has been given.

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Strains of medium and coarse varieties

IMPROVED RICE STRAINS IN THE CENTRAL PROVINCES

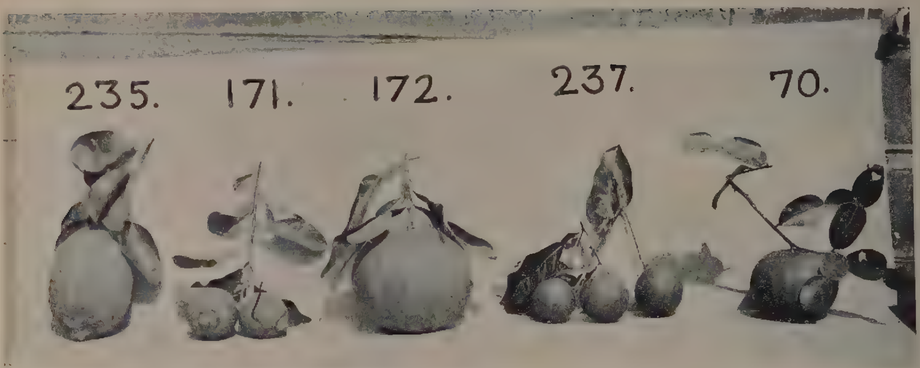

Fig. 1. The typical fruits of different stock types—No. 235 (*Pani jamir*), No. 171 (*Sohmyndong*), No. 172 (*Rababtenga*), No. 237 (*Karun jamir*), and No. 70 (*Satkora*)

Fig. 2. The root and shoot systems of a typical plant of Khasi orange budded on each different stock variety No. 235 (*Pani jamir*), No. 171 (*Sohmyndong*), No. 172 (*Rababtenga*), No. 237 (*Karun jamir*), and No. 70 (*Satkora*)

NURSERY BEHAVIOUR OF FIVE INDIGENOUS CITRUS ROOTSTOCK VARIETIES WITH KHASI ORANGE AS SCION IN ASSAM

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(Received for publication on 19 March 1943)

(With Plate XXI)

The loose-skinned orange of Assam—*Citrus nobilis* Lour, popularly known as Khasi orange—is *par excellence* the most important commercial fruit variety of the province. The area under this fruit variety alone is estimated to be 20,000 acres. In comparatively recent years the cultivation of this fruit variety has been rapidly expanding, notably in the plain districts.

The Khasi orange is propagated exclusively from seeds and it comes remarkably true to the type. The obvious explanation of this striking uniformity of seedling trees probably lies in the highly polyembryonic characters of the seeds. The extent of polyembryony has been estimated at germination to be about 30 per cent. It is likely that the extent of polyembryony is still higher, for a seed giving rise to one seedling at germination need not necessarily be monoembryonic.

The orange trees are grown exclusively as a rain-fed crop and receive neither any cultivation nor any manuring throughout their life-periods. The only care consists of cleaning the undergrowth once a year at the time of the harvest. The trees usually come to their maiden bearing on the eighth year and to regular bearing from the tenth year onwards.

In plantations situated under favourable soil and climatic conditions, the trees do really enjoy a long span of profitable life, combining quality with yield. But in majority of plantations, particularly those in the plain districts, the performances of the trees on their own roots have been far from satisfactory. Generally they suffer from lack of vigour and are consequently short-lived, low-yielding and manifest symptoms of yellowing disease. These are some of the serious problems confronting the growers and the future expansion of orange cultivation in the province hinges more or less on their successful solution.

The aim of the present investigation is to find out a suitable rootstock for Khasi orange that will grow successfully in those places where seedling trees have manifestly failed on their own roots. Moreover, the advantage of an early-bearing habit is yet another point in favour of budded trees which deserves attention.

Many varieties of citrus are cultivated and a few grow wild in this province and it is practically impossible to try all of them simultaneously as a stock for Khasi orange on an experimental scale. The investigation has, therefore, been confined for the present to a study of the nursery behaviour of five selected indigenous rootstock varieties only.

The present paper deals only with the nursery phase of the budded plants of different combinations. The behaviour of the plants in the field will be dealt with in due course. The work was carried out at the Citrus Fruits Research Station, Burnihat, Assam.

The problem of stock-scion compatibility in citrus is one of great complexity inasmuch as environment plays a great part in deciding the behaviour of any particular stock-scion combination. An example to the point is the behaviour of sour orange. This stock variety which is so successfully employed for propagation of sweet orange in California and other places has been found to be quite unsuitable for the same scion type in South Africa, Java and Peshawar [Webber, 1926; Toxopeus, 1936; Brown, 1920]. Richard [1938] working in Ceylon observed that the Walter's and Marsh's seedless grape-fruits worked on shaddock produced chlorotic symptoms on the leaves in the dry zone of the country but the same graft combination behaved quite normally in the wet zone. Argle [1937] while summing up the position stated that incompatibility might be solely due to inherent structural and physiological differences of two symbionts but unfavourable soil and climatic conditions might also induce incompatibility in some combinations of stocks and scions, which otherwise would be quite compatible. Consequently a graft combination found suitable under one set of conditions might not necessarily behave alike in another set of conditions. All available evidences on stock-scion compatibility in citrus point to the necessity of local experimentation for testing the merits and demerits of particular stock-scion combinations.

Rootstocks employed

1. *Rababtenga No. 172.* Shaddock—*Citrus maxima* Merril—*Batabi nebu* of Bengal, *Chakotra* of the Punjab. This is found to grow everywhere in the plain districts. The type employed for the trial is the red-vesicled one.

2. *Sohmyndong No. 171.* Rough lemon—*Citrus limonia* Osbeck—*Jamburi* of Bombay and the Central Provinces, *Jati-khatti* of the Punjab, *Kata-lebu* of Bengal. This variety is known to have wide adaptability and grows both in the plain and in hills up to an altitude of about 4000 ft. It has been found to grow very luxuriantly in poor soils particularly on the hill slopes. The type employed is the real rough lemon with its characteristic nipple. The fruits are highly acidic.

3. *Pani jamir No. 235. Muri-tenga* in Assamese —*Citrus limonia* Osbeck. This variety is usually met with in the plains and very occasionally on low hills and is indigenous to the province. Fruits are oblong, of medium size with a mamillate apex, juice is plenty. Sweetness well-blended with acid.

4. *Karun jamir No. 237.* Seville orange—*Citrus aurantium* Linn.—*Khatta* of the Punjab. This variety is indigenous to the province and has been found to grow wild in Sibsagar district. It is known in Assamese as *Tita karuna* meaning a bitter fruit.

5. *Satkora No. 70* (*C. hystrix*). This is probably the tallest and most well-built tree in whole of the genus but it is extremely slow in growth. A five-year old plant barely reaches 3 ft. in height. This is found to grow wild in north Cachar hills. The trees are very prolific in bearing and the sour fruits form a steady source of revenue to the Forest Department. There are two types in this species. The one with retuse apex of the leaf blade has been used for this trial. A photograph of typical fruits of the five stock varieties is furnished for easy identification (Plate XXI, fig. 1).

Materials and methods

Seeds of different stock varieties detailed above were obtained from a particular selected tree of each. The seeds of all the varieties except *Satkora* were sown in the seed-bed on 25 November 1939 and after elimination of weak seedlings the remainders were transplanted in the nursery on 14 July 1940. The seeds of *Satkora*, however, were sown in the seed-bed on 15 November 1938, i.e. in the previous year and the seedlings were transplanted in the nursery on 10 June 1939. This was necessary as seedlings of *Satkora* are remarkably slow in growth and do not attain a buddable size till about 30-35 months old. Seedlings of all the varieties were accommodated in one nursery plot and were planted in rows 4 ft. apart with a spacing of 2 ft. between plants. To obtain greater uniformity of stock materials a second elimination was carried out in the nursery rejecting very vigorous and weak seedlings [Webber, 1932] and finally 75 plants of each stock type except *Satkora* were selected for bud insertion. For *Satkora* only 46 plants that had attained a buddable size were selected.

Budding on all the varieties was carried out at a uniform height of 8 in. from the ground level between 24 and 28 December 1940. The bud-wood was obtained from a single Khasi orange tree and the same budder was employed for all the operations. Out of 75 budded plants of each stock variety, 50 were again selected on the basis of earliness of bud-break, whereas in the case of *Satkora*, 43 plants that received the bud successfully had to be accepted.

Height and girth measurements of each individual plant were recorded just prior to budding. One month after bud-insertion, the top of each plant was lopped off at an height of 8 in. above the bud-union and the top weight of each individual plant was recorded [Webber, 1932].

The mean height, mean stem diameter and mean top weight, percentage of success in budding, the mean period of bud-break, coefficient of variability of the seedling of different stock type and their significance of difference are shown in Table I.

TABLE I

Stock	Age of stock seedlings at budding (M. Days)	No. of budded plant	Mean height in cm.	S. E.	C. V.	Mean stem diameter in mm.	S. E.	C. V.	Mean top weight in oz.	S. E.	C. V.	Percentage budding success	Mean period of bud, break in days	S. E.	C. V.
A. *Rababtenga* (shaddock)	11—16	50	62·02	1·11	12·65	8·84	0·13	10·39	1·18	0·06	35·92	88·0	75·72	1·75	16·40
B. *Sohmyndong* (rough lemon)	11—9	50	71·82	1·82	14·99	9·34	0·17	12·87	0·70	0·05	50·27	97·33	51·06	2·21	29·06
C. *Pani jamir* (lemon)	11—7	50	66·48	1·55	16·47	10·38	0·22	14·85	1·10	0·08	50·97	90·00	59·60	1·36	16·19
D. *Karun jamir* (savelle orange)	11—9	50	50·44	1·55	21·71	7·56	0·14	13·08	0·47	0·04	54·51	93·33	62·96	2·06	23·12
E. *Satkora* (*C. hystrix*)	32—19	43	25·95	0·68	17·19	7·51	0·15	13·05	0·47	0·05	54·38	93·47	45·85	1·19	16·99

Conclusion at 5 per cent level of significance

Height . . . . . . B C A D E

Stem diameter . . . . C B A D E

Top Weight . . . . A C B D E

Period of bud-break in days . A D C B E

REMARKS—Treatments above same bar do not differ significantly from each other

Sohmyndong occupies the first and second position as regards height and stem diameter respectively but stands third as regards top weight, whereas *Rababtenga* which occupies the third position both in regard to height and stem diameter occupies the first place as regards growth. It seems that these characters can be relied on as indices of vigour within the variety but are not helpful for inter-varietal comparison. One variety might spend its energy in attaining height, another in diameter and the third might manifest itself in top growth. One seedling of each stock variety was lifted with a view to studying their respective root-systems. The plants were excavated between 2 and 6 March 1942, with minute care tracing the roots as far as practicable to their very tip. The age of plants (except for *Satkora*) at the time of excavation varied from 13 months and 19 days to 13 months and 26 days and the age of *Satkora* plant was 35 months and 3 days.

TABLE II

Data of root-system of different stock varieties

Stock	Height of plant in cm.	Diameter of stem in mm. above ground level	Weight of shoots in gm.	No. of laterals	Maximum spread in cm.	Maximum penetration in cm.	Weight of roots in gm.	Weight of coarse roots in gm.	Weight of fibre roots in gm.	Ratio-shoot weight / Root weight	Ratio-height / maximum penetration
A. *Rababtenga* (shaddock)	61	14	78·13	18	36	65	11·11	7·86	3·25	7·08	0·94
B. *Sohmyndong* (rough lemon)	75	11	70·75	13	45	47	11·96	9·38	2·58	5·91	1·59
C. *Pani jamir*	64	16	99·05	22	66	37	22·40	17·05	5·35	4·42	1·65
D. *Karun jamir*	51	10	35·37	19	40	62	8·46	6·78	1·68	4·18	0·82
E. *Satkora*	28	8	21·31	10	22	46	5·61	5·03	0·58	3·80	0·63

The data furnished above can claim no scientific accuracy as it is based on the root-system of one plant only. Nevertheless, inferences may apparently be drawn on the basis of striking differences between different root-systems. *Pani jamir* seems to be a surface rooter having the greatest number of laterals spreading over maximum length and with the highest quantity of roots. Roots of *Rababtenga* and *Karun jamir* are more or less alike in their ramification and tend to go deep into the soil. *Sohmyndong* occupies an intermediate position both in spread and penetration of the roots. The root-system of *Satkora* alike its shoot system is very slow in growth but the roots seem to grow faster than the shoots. A photograph of root-system of different stock varieties is furnished for vivid comparison (Plate XXI, fig. 2). Out of 50 budded plants of each stock type and 43 of *Satkora* propagated in the nursery, 24 budded plants of each stock type, representing the experimental needs, were finally selected on the basis of uniformity of growth of scion and were planted in the field during May, 1942, according to the approved plan. Measurements for height and thickness of stem of each individual plant were recorded immediately before removal from the nursery.

The growth of Khasi orange scion on different rootstock varieties, recorded in the nursery after two years and four months from the date of budding, are shown in Table III.

DISCUSSION

Observations carried out in the nursery reveal a visibly different behaviour of plants of different stock-scion combinations (Plate XXI, fig. 2) which are discussed below:

On *Pani jamir* (lemon), the scion has made a strikingly vigorous growth with a characteristic deep-green leaves. This stock variety is indigenous to the province and grows almost everywhere. It has a very vigorous root-system spread over a considerable area.

On *Sohmyndong* (rough lemon), the scion has also made appreciable growth but the leaves are somewhat light green although the plants are quite healthy. This rootstock is very widely used both in India and abroad and has not been reported so far to be incompatible with any scion variety under any environmental condition. It has been favourably reported in the Punjab, where it has been studied up to the vegetative stage as a rootstock for Santra [Lal Singh and Sham Singh, 1942].

On *Rababtenga* (shaddock), the plants have shown medium growth but some of the leaves in a few plants have manifest chlorotic symptoms, though unbudded plants of shaddock growing side by side have not been found to be chlorotic in appearance. As a stock for Mandarin similar behaviour had been observed by Lee [1921] in Philippines with shaddock though shaddock

budded on Mandarin did not manifest chlorotic symptoms on the leaves. Shaddock as a rootstock for Santra has not yet been tested anywhere else in India. On the basis of our observation in the nursery, it can be stated that **shaddock is at least partially incompatible as a stock for Khasi orange.** Besides this stock is extremely susceptible to attack of scale insects.

TABLE III

Rootstock	Mean height of scion from ground level in cm.	S. E.	Mean diameter of stock 3 in. above ground level in mm.	S. E.	Mean diameter of scion 3 in. above bud-scion in mm.	S. E.
A. *Rababtenga*(shaddock)	79·04	1·85	17·79	0·43	13·04	0·42
B. *Sohmyndong* (rough lemon) . . .	95·94	2·02	16·88	0·31	13·92	0·40
C. *Pani Jamir* (lemon)	102·04	2·13	19·08	0·39	14·21	0·48
D. *Karun Jamir* (seville orange) . . .	72·29	2·69	13·42	0·45	10·92	0·33
E. *Satkora* (*C. hystrix*)	55·67	1·97	11·79	1·31	8·67	0·34

Symbolical representation of results at 5 per cent level
Height of scion from ground level—C B A D E
Thickness of stem of scion 3 in. above bud-scion—C B A D E
Thickness of rootstock 3 in. above ground level—$\overline{\text{C A B}}$ D E

On *Satkora* stock (*Citrus hystrix*), the budlings have shown minimum growth, even though they have outgrown the slow-growing unbudded plants of *Satkora* of the same age growing side by side at about 8 in. The budded plants have a distinctly healthy look and the leaves are deep-green. It is difficult to state at this early stage whether the stock will ultimately induce any dwarfing effect on the growth of the scion. It is, however, clear that the slow-growing rootstock of *Satkora* has **attributed the slow-growing character to the scion** as well and as such this stock variety cannot hold out much promise to the commercial growers. Another drawback with this stock is that the stem does not grow straight and the short internodal length is a distinct disadvantage for bud insertion. It appears that this variety was tried as a stock in Dominica [1931], where the trees started growth very vigorously but were ultimately killed by foot-rot. *Satkora* grows normally in the hills but suffers from arrested growth when put in the plains. This distinctive behaviour is another point against its general adoption as a stock.

The initial growth of budling on *Karun jamir* (Seville orange) was quite normal but within four months from the date of budding, 32 per cent of the budded plants developed complete yellowing and 7 per cent manifested partial chlorosis on the leaves. Even liberal application of farmyard manure and periodical irrigation could not bring about any perceptible improvements in the plants. Unbudded plants of *Karun jamir*, growing side by side did not, however, show the slightest trace of chlorosis or yellowing symptoms on the leaves. The question arises why all the budded plants, without any exception, did not develop the chlorotic symptoms, specially when all the stock seedlings were progenies of one single tree. If incompatibility is the main contributory cause, all the budded plants ought to have behaved alike. It is probable that as the stock plants were not raised vegetatively, the variable behaviour within the type might be the direct result of natural cross-pollination which would produce seedlings with variable genetical constitution. It may, however, be added that even those budded plants which did not manifest either chlorosis or yellowing on foliage, suffered from a general unhealthy look. As such there can be no doubt about the incompatibility of this stock-scion combination. The Seville orange has been reported to be incompatible for *Satsuma* both by Hume [1930] and Swingle [1927], but this stock was, however, found to be quite compatible with Santra in north-west India [Brown 1920, 1928]. As a stock for sweet orange, Seville orange has been found to be compatible in Florida and incompatible in South Africa and Java [Webber, 1926; Toxopeus, 1936]. The differential reaction of this variety to the same Santra scion in Assam and in Peshawar is another instance in support of the statement of Prof. V. A. Blackman that 'the success of graft like that of a marriage may depend not only on the inherent qualities of the two

individuals but also on the conditions, favourable or unfavourable, to which they are exposed during their partnership'.

Summary

An investigation to test the suitability of five indigenous citrus varieties as rootstocks for Khasi orange scion in Assam was carried out. The present paper deals with the nursery phase of the budded plants of different combinations.

The scion has made most vigorous and healthy growth on *Pani jamir* (*Citrus limonia* Osbeck) and attained a mean height of 102·04 cm. within 28 months from the date of budding. On *Sohmyndong* (rough lemon), the scion attained a height of 95·04 cm. within the same period. On *Rababtenga* (shaddock), the scion has attained a height of 79·03 cm. but a few of the plants have developed chlorotic symptoms on the leaves and as such this stock is not likely to be suitable for the propagation of this particular scion type. On *Karun jamir* (Seville orange), the scion attained a mean height of 79·29 cm., but 32 per cent of the budded plants developed complete yellowing and 7 per cent partial chlorosis. Even those plants free from chlorosis and yellowing suffer from a general unhealthy look. As such, this stock variety seems to be incompatible as a stock for Khasi orange scion. On *Satkora* (*Citrus hystrix*), the scion has made very slow growth attaining a mean height of only 55·67 cm., but the plants have a distinctly healthy appearance. *Satkora* has been found to be a very slow grower and it seems that the stock has contributed its slow-growing habit to the scion as well.

Unbudded plants of *Rababtenga* (shaddock) and *Karun jamir* (Seville orange) have not shown chlorotic and yellowing symptoms. Stock-scion incompatibility is probably a contributory cause for yellowing and chlorotic diseases.

A comparative study of the root-systems of the five stock varieties which were about 13 months old show that *Pani jamir* has got the most vigorous root-systems with maximum spread and weight of roots. This vigorous root-system is correlated with the maximum growth of the scion. The root-system of *Satkora* alike its shoot system is very slow in growth and this is responsible for the slow growth of the scion.

Acknowledgement

Authors' thanks are due to the Imperial Council of Agricultural Research, New Delhi, for partly financing the scheme under which this investigation was carried out. Our thanks are also due to Mr R. C. Woodford, Director of Agriculture, Assam, for his keen interest in the work and various practical suggestions given by him.

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THE EFFECT OF STORAGE UNDER CERTAIN SPECIFIED CONDITIONS ON THE QUALITY OF INDIAN COTTONS

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(Received for publication on 14 December 1942)

(With two text-figures)

Sometime back an investigation was carried out at the Laboratory [Gulati, 1937] on the effects of storing Broach-Palej cotton with special reference to the growth of fungi and bacteria in the stored cotton, the damage to its fibres and the discolouration of its surface. This cotton was selected partly because Broach forms the basis of the most active 'hedge' contract in the Bombay market and partly because there is a widespread impression in the trade that this cotton is readily susceptible to changes in colour on storage. It was found that the damage to fibres and the discolouration of the cotton were mainly due to the growth on the cotton of fungi, which thrived especially in a humid and warm atmosphere such as prevails in Bombay during certain months of the year. In all, 18 different species of fungi and three types of bacteria were isolated from the stored sample, and it was found that the stained and matted parts of the cotton constituted seats of heavier infection than the clean portions. These results were reported by one of us at the First Conference of Scientific Research Workers on Cotton in India and an account was published in its proceedings.

An improved variety, known as Broach Deshi 8, has been developed to replace Broach cotton in certain districts. In view of the importance of Broach cotton to the trade, it was decided to continue this investigation on B. D. 8 cotton on more exhaustive lines and the results obtained are described in this paper. This investigation was divided into three parts. In the first part, a bale of B. D. 8 was obtained and stored for about 2½ years in the store-room of the Laboratory under conditions normally prevailing in Bombay. Samples at regular intervals of six months were drawn from this bale and were subjected to a number of tests which will be described hereafter. In the second part of this investigation, small samples of B. D. 8 and Broach cotton were kept over different humidities in enclosed space inside desiccators, and the changes in fibre-strength, shade and incidence of infection of these samples were studied every month for about two years. In the third part of this investigation the effect of localized watering on 11 different cottons, which were stored under different conditions of humidity were studied. The results of each part of the investigation will now be described.

Experimental procedure

As stated above, the first part of the study was carried out on a bale of B. D. 8 cotton, which was stored in the store-room of the Laboratory and studies were commenced on it in April 1937. It was taken to a local pressing factory every six months when a sample weighing about 25 lb. was drawn from it, after which it was repressed and brought back to the Laboratory. The bale was kept under observation in this manner for 2½ years during which six samples were drawn from it.

Each of these samples was tested for its fibre properties and spinning performance and was further subjected to tests for damage to fibre. Furthermore, the opinion of the Appeal Committee of the East India Cotton Association was invited on these samples, while the fungi infesting the first and the last samples were isolated.

For the second part of the study a sample weighing 35 gm. of cotton was placed inside a desiccator in which the required humidity was maintained with the help of calcium chloride solutions or distilled water, the strength of the former being as recommended by Paranjpe [1918]. The four relative humidities selected for this purpose were 60, 75, 90 and 100 per cent. These tests were made on both B. D. 8 and Broach-Palej cottons. The desiccators were large enough to provide ample air space around the samples of cotton. The lids of the desiccators were stuck with petroleum jelly and were further held by broad rubber bands which were fixed with molten paraffin so as to insure air-tight joints. The cotton in each desiccator rested on an improvised glass stand which was supported on a perforated porcelain disc.

Small samples from the cotton stored in this manner were drawn once a month for two years for strength and infection tests. For this purpose, the desiccators were opened in an atmosphere corresponding to their humidities inside a room in which both humidity and temperature could be varied over a fairly wide range.

As a part of this study, both cottons were also kept for shade measurements in deep petri dishes

in which the above-mentioned four humidities were maintained. The cotton in each dish was surfaced evenly and covered with a glass lid which was fastened to the dish. Measurements were made on these dishes for change in shade once a month for two years.

In the third part of this study the effect of localized watering on cotton stored at different humidities was investigated for 11 cottons in the following manner:

A sample weighing 30 gm. was divided into two equal parts, each of which was shaped like a circular pad. The central portion of each pad was made fairly even and four areas measuring $\frac{7}{8}$ in. $\times$ $\frac{7}{8}$ in. were marked on one of them with paper strips held down with stainless steel pins. Both the paper strips and the pins were sterilized at 15 lb. pressure for 20 minutes.

Each of the four areas was moistened by means of a De Vilbiss atomiser with 2 c.c. of sterile water so that 8 c.c. of water was sprayed on one pad. The dry pad was then placed over the moist pad and the two pads were transferred to a desiccator set up for the required humidity of storage. Three humidities, namely, dry (over anhydrous calcium chloride), 60 per cent R.H. and 90 per cent R.H. were tried in this experiment. The bundle strength of the cotton before and after watering and storage was determined, the period of storage being 21 days.

The effects of adding different anti-septics to the water used for localized watering were also studied in the above experiments.

Details of tests

The technique and the apparatus employed in the following tests, namely, bundle-strength, fungal infection tests, isolation of fungi, and shade measurements are described here. The methods employed in the remaining tests will be found in an earlier publication by one of us [Ahmad, 1933], with the exception of the fungal damage test which is described by Bright [1926].

(*a*) *Bundle-strength of cotton fibres*. A small tuft of fibres containing 80-120 fibres is drawn through a set of combs to remove stray or matted fibres, and its ends are fixed with Dunlop rubber solution to small strips of thick black paper leaving the middle 8 mm. length of fibres exposed for the strength test. The test length of 8 mm. was chosen owing to the comparatively short staple length of Broach-Palej cotton. The paper strips were held in the jaws of a Schopper Strength Testing Machine, of the constant rate of loading type. The tufts were conditioned at 70 per cent R. H. for one hour before breaking at the same humidity. Twenty bundles were broken for every sample and the coefficient of variation was found to be 16 per cent.

(*b*) *Incidence of fungal infection*. Fungal infection on cotton fibres was studied under a microscope with the help of cotton blue dissolved in lactophenol. This reagent has a special affinity for micro-organisms and does not ordinarily stain the uninfected cotton fibre. The fibres to be examined were mounted in the above-mentioned reagent on a glass slide and were left overnight. The infected fibres took up the stain and could be easily distinguished from the uninfected ones.

(*c*) *Isolation of fungi from cotton fibres*. In order to get as large a variety as possible of organisms present in various parts of lint, stained, soiled and colourless fibres were picked out. Two such tufts of fibres were cut into small bits, which were mixed together, and small lumps taken from the heap were inoculated in melted medium contained in glass tubes and poured into petri dishes.

The number of colonies of micro-organisms was noted from day to day for a week on plates. They usually appeared on the third day at the room temperature.

The identification of fungi in each type of colony was based on structural appearance.

(*d*) *Changes in shade of lint*. These measurements were made with an apparatus designed specially for this purpose by one of us. Briefly the apparatus consists of two rectangular boxes with square cross-section, joined at right angles to each other and open at the lower end of the junction. These boxes are lined on the inside with mirrors on three sides and black velveteen on the lower or fourth side. The right-hand box supports a photo-electric cell, while the other box has a casing fitted to it which holds an electric bulb. The dishes containing cotton with evenly prepared surfaces, kept at different humidities, are brought one by one under the opening at the junction of the boxes and raised to a constant level by an adjustable table **(Fig. 1)**.

Some of the light falling on the surface of cotton is reflected to the photo-electric cell. The P.E.C. develops an electromotive force which is measured on a potentiometer by balancing it against the current from a 2-volt battery.

In order to avoid fluctuations in the intensity of light due to changes in the current from the mains an amperemeter is included in the circuit along with a variable rheostat and all the readings are taken at a constant current. Similarly, the battery voltage against which the E.M.F. of the P.E.C. is balanced is read on a sensitive volt-meter for every reading, which is adjusted for a constant voltage for comparative purposes.

The readings of reflection from the surface of cotton are compared to those taken from the surface of a white plate which was considered as a standard non-changing surface for the purpose of

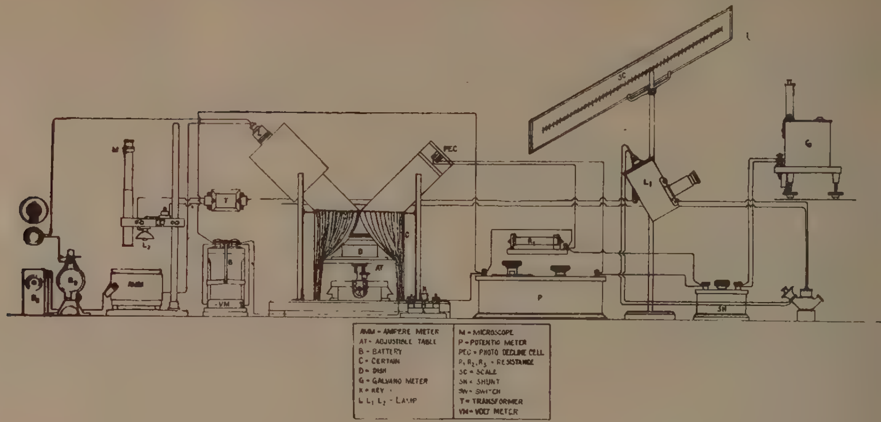

FIG. 1.

this experiment. The relative whiteness of the samples was thus shown by the ratio :

$$\frac{\text{E.M.F. developed with cotton surface}}{\text{E.M.F. developed with white plate}}$$

RESULTS

The results of the various tests carried out in the course of this investigation are presented in Tables I to XV. For the sake of both clarity and convenience, it is proposed to discuss separately the data of the three parts of this investigation referred before.

DISCUSSION

I. *Storage in bale*

The results of the tests carried out on the samples of B. D. 8 drawn at intervals of six months may be considered under the following six sub-heads :

(1) Valuation by Appeal Committee of the East India Cotton Association, Bombay.

(2) Fibre properties.

(3) Spinning behaviour.

(4) Yarn strength and extension.

(5) Congo Red damage test.

(6) Identification of fungi before and after storage.

Valuation by the Appeal Committee. A representative sample weighing about ½ lb. from each drawing was sent to the Appeal Committee of the East India Cotton Association, Bombay, for opinion on class, colour, staple, etc. The results of their valuation are embodied in Table I. A study of this table shows that the cotton which was classed as fully good to fine in the first drawing remained fully good in the next two drawings ; but deteriorated to Broach in the fourth drawing, and continued to be classed as such in subsequent drawings. It will be noted that the guiding considerations in the classifications are colour, the amount of stain, the character of leaf seed bits and motes, etc. Whereas the first drawing was creamy-white with some stain and sligtly leafy, the second drawing was set down as being very discoloured and yellow. This change persisted in the third and fourth drawings and worsened slightly in the subsequent drawings. A fall in staple length was also felt to have taken place in the fourth drawing and another one in the last drawing. A gradual deterioration of B. D. 8 was, thus, indicated which was reflected in the value 'above or below' the basis.

Fibre properties. Three fibre properties, namely, mean fibre-length, fibre-weight per unit length, and fibre-strength were determined by the usual methods and the values obtained are given in columns 3 to 6 of Table II.

Taking each property separately, it is found that mean fibre-length does not show any appreciable change except in the last drawing when a fall of 0·045 in. is recorded, which confirms the independent observation of the Appeal Committee. It is unlikely that the mean fibre-length of a cotton should decrease on storage, the observed effect may therefore be due to sampling or to the presence in the bale of a layer of lower mean length from which the last sample was drawn. Alternately, it may be due to the break-up of some fibres in the repeated opening and re-pressing processes of the bale, especially if the fibres are weakened by internal corrosion.

The fibre-weight values per inch show irregular variation. Normally it would be expected that the values obtained before the monsoon would be somewhat lower than those obtained after the monsoon, as during the monsoon the cotton would be able to absorb some moisture. A similar effect was noticed by Ahmad [1936], when several bales of cotton were stored at Karachi for a year and a

TABLE I

Reports of the Appeal Committee of the East India Cotton Association, Bombay, on six-monthly drawings from a bale of B. D. 8 cotton

Grading features	Number and dates of drawings					
	1	2	3	4	5	6
	20-4-37	22-11-37	25-4-38	17-10-38	17-4-39	10-10-39
Class	Fully good to fine	Fully good	Fully good	Broach	Broach	Broach
Colour	Creamy white; some stains and slightly leafy	Very discoloured (yellow), below fully good Broach; much handled. Leaf: fine Broach	Very discoloured (yellow), little better than the good Broach standard of 1936-37; much handled. Leaf: fine Broach	Very discoloured (yellow), more so than the good Broach standard 1937-38; much handled. Leaf: fine Broach	Very much discoloured and handled; about the same as good Broach standard 1937-38. Leaf turned dark brown	Very much discoloured and handled; 1/2 grade lower than good Broach standard 1938-39. Leaf: peppery and broken
Staple Length	13/16-in.	13/16 in.	13/16 in.	25/32 in.	25/32 in.	3/4 in.
Staple Strength	Good	..	..	..	..	..
Regularity	Regular	..	..	..	..	..
Value above or below contract rate	Rs. 25 on	Rs. 10 on	Rs. 15 on	Rs. 3 off	Rs. 10 off	Rs.5 on.
Basis of contract per candy	F. G. Broach July/Aug. 1937 delivery Rs. 229	F. G. Broach April/May 1938 delivery Rs. 162	F. G. Broach Apr./May 1938 delivery Rs. 159	Broach April/May 1939 delivery Rs. 155	Broach April/May 1939 delivery Rs. 155	Broach April/May 1940 delivery Rs. 195
Date of valuation	14-6-37	25-11-37	4-5-38	4-11-38	21-4-39	23-10-39

Note.—Observations were commenced one year after the date of purchase of the bale which was 8-4-1936

TABLE II

Fibre properties of samples of B. D. 8 cotton drawn every six months from the stored bale

No. of drawing	Date of drawing	Fibre properties			
		Fibre-length (in.)	Fibre-weight per inch (10^{-6}oz.)	Fibre-strength (oz.)	Bundle strength of 100 fibres (oz.)
1	20-4-1937	0·855	0·187	0·188	10·45
2	22-11-1937	0·845	0·208	0·160	9·50
3	25-4-1938	0·855	0·189	0·187	10·21
4	17-10-1938	0·865	0·187	0·182	9·19
5	17-4-1939	0·860	0·216	0·195	11·44
6	10-10-1939	0·815	0·199	0·202	9·74
S. E.		0·010	0·008	0·006	0·32

N.B.—The number of independent readings taken for each property are as follows:

Mean fibre-length	..	3 sorter determinations
Fibre-weight per inch	.	16 on 1600 fibres in groups of 100 fibres each
Fibre-strength	..	400 fibres
Bundle strength	...	20 bundles, each of 100 fibres

half and samples were drawn and tested at regular intervals. In the present case such an effect is shown only by the first three values; the next three do not show any such effect. The absence of regular variation is probably due to the fact that the determination of fibre-weight per inch was not carried out in all cases immediately after the samples were drawn, and in view of this irregular variation, which is contrary to what one would expect from *a priori* reasoning, no further discussion of these values is necessary.

The fibre-strength values show irregular variation, but the bundle-strength, which is less susceptible to sampling error, shows alternate rise and fall in its values. In this case, however, it is probable that the temperature, too, has an effect, as on looking up the records, it is noticed that, in general, a relatively high bundle-strength is associated with a comparatively high temperature. The values, however, are too few to lead to definite conclusions, and it is proposed to elucidate this point by further tests. It should, however, be noted that there is no progressive decrease in the strength of the fibres, denoted either by single fibre or bundle strength on storage of this cotton in bale for over two years.

Spinning behaviour. The spinning behaviour of the six samples drawn from the stored bale is in columns 3-7 of Table III.

TABLE III

Spinning performance of the samples drawn at six monthly interval from the stored bale of B. D. 8 cotton

No. of drawing	Date of drawing	Spinning behaviour: Blow-room loss per cent	Card-room loss per cent	Yarn breakages per 100 spindles per hour	Mean neps per yard	Mean evenness class	Lot No.	Single-thread strength (oz.) for counts: 20's	24's	30's	34's	Mean	Extension percentages: 20's	24's	30's	34's	Mean	Lea strength (lb.): 20's	24's	30's	34's	Mean	Mean R. H. per cent during 6 months at 8 a.m. L.M.T.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	20-4-37	6·3	8·9	6	1·2	3⅜	I	14·0	11·7	8·5	7·1	10·19	6·3	6·2	5·3	5·3	5·92	106·4	81·8	60·8	47·0	71·0	—
							II	13·8	11·1	8·4	6·9		6·6	6·4	5·9	5·4		97·5	71·7	56·2	46·5		
2	22-11-37	7·6	8·8	11	1·1	3¼	I	13·1	10·4	7·2	6·2	9·30	7·2	6·6	5·8	5·7	6·66	98·4	75·9	53·5	42·6	67·4	81
							II	12·8	10·3	7·5	6·9		7·4	7·2	6·8	6·6		96·6	74·7	54·1	43·2		
3	25-4-38	6·5	8·5	19	0·9	3⅝	I	12·8	10·5	8·0	6·6	9·18	7·3	7·1	6·8	6·4	6·60	88·3	65·5	47·4	36·4	56·7	70
							II	13·0	9·9	6·9	5·7		7·0	6·6	5·9	5·7		79·2	56·8	45·2	34·5		
4	17-10-38	6·0	8·3	10	1·0	3⅞	I	12·9	10·2	7·0	6·1	8·85	7·0	7·1	6·2	5·9	6·48	91·4	68·7	50·1	40·2	61·3	84
							II	11·5	9·7	7·1	6·3		7·0	6·8	6·4	5·4		90·5	66·2	45·1	38·1		
5	17-4-39	6·8	7·2	19	0·4	4⅛	I	11·7	8·5	6·4	5·1	7·91	8·0	7·2	6·8	6·3	7·20	85·6	67·2	47·6	36·1	58·5	72
							II	10·9	9·6	6·0	5·1		7·7	7·7	7·1	6·8		85·2	64·5	45·8	36·3		
6	10-10-39	6·2	7·8	43	0·8	3¾	I	11·2	9·5	7·1	6·1	8·49	7·8	7·5	6·8	6·2	6·51	88·0	62·9	42·2	32·1	55·4	81
							II	12·0	9·7	6·8	5·5		6·8	6·2	5·5	5·3		87·4	59·7	39·7	31·5		
								S. E. =0·383					S. E.=0·382					S. E.=2·86					

The blow-room loss appears to be unaffected by storage, but the card-room loss shows a small tendency to decrease. This fall in the card-room loss is most probably due to the partial loss of trash (leaf and seed bits) at the time of each successive drawing when the cotton was mixed up before re-pressing the bale. It is noteworthy that the only exception to the general trend occurs in the last drawing, when as observed earlier, the staple was found to be slightly shorter. If the decrease in mean length was due to the break-up of some fibres, then it would have the effect of increasing the card loss by a small amount.

Yarn breakages in the ring frame show a tendency to increase with the lapse of time—this increase being most pronounced in the final drawing. Yarn breakage is a complex character depending upon a number of factors, but to the extent that it is an indication of the behaviour of cotton in spinning, the data indicate deterioration of this cotton with lapse of time.

The evenness class of the yarns appears to be unaffected by storage. Neps per yard also do not show much variation from sample to sample except in the last two samples. Thus, both these features do not indicate any significant change brought about by storage of cotton for over two years.

Yarn characteristics. The results of yarn tests for single-thread strength, extension percentage and lea strength are given in columns 8 to 23 of Table III. These results being complete in respect of six drawings, four counts and two determinations for each count are well suited for analysis of variance which has been applied to them as shown in Table IV. By this method the effect of storage is sorted out from the effect of counts which would obviously be highly significant.

TABLE IV

Analysis of variance

Factors	Degrees of freedom	Single-thread strength		Extension percentage		Lea strength	
		Sum of squares	Mean squares	Sum of squares	Mean squares	Sum of squares	Mean squares
Storage	5	23·98	4·80**	6·67	1·33**	1545·83	309·17**
Counts	3	294·91	98·30	11·73	3·99	19206·65	6402·22
Error (residual)	39	5·75	0·147	5·71	0·146	319·84	8·20
Total	47	324·64	..	24·11	..	21072·32	..
Storage—							
Linear comp.	1	19·14	19·14**	2·24	2·24**	1134·52	1134·52**
Parabolic comp. of 2nd degree	1	1·71	1·71**	1·50	1·50**	112·83	112·83**
Deviations	3	3·13	1·04**	2·93	0·98**	298·48	99·83**
Total		23·98		6·67		1545·83	

** Indicates significance at 1 per cent level

It is interesting to note that the effect of storage is highly significant for all the three characteristics as will be seen from the analysis given in Table IV. There is, however, this difference that while the single-thread strength and lea strength decrease with lapse of time, the extension percentage, on the other hand, shows a tendency to increase. We shall consider the results for each characteristic separately. It will be observed that each sample was spun into two lots and each lot into four counts. As the results for each count are subject to a certain amount of sampling error we shall consider the results for all the four counts together, and for this purpose the mean values for the three characteristics are plotted out in Fig. 2.

The curve for lea strength shows some fluctuations superimposed upon a general downward trend with increase in the period of storage. We notice a tendency for the lea strength to decrease up to the 3rd drawing after which it increases in the 4th drawing and then again falls in the 5th and the 6th drawings. Thus, a fall occurs in the 3rd and 6th drawings, after a storage of one year in either case. Judging by the S. E. given in Table III it will be seen that the value for the 2nd drawing, after six months' storage, is less than that for the first drawing, but the difference is not significant. A further storage of six months, however, brought about a considerable decrease in lea strength and the value for the 3rd drawing was

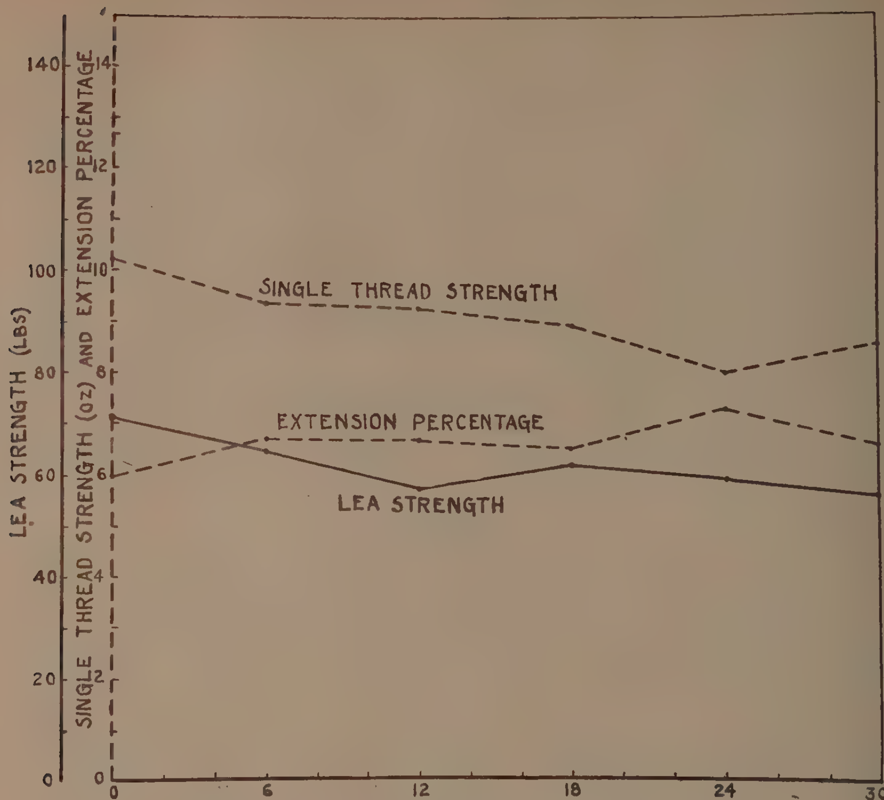

FIG. 2. Storage period (months—April 1937 to October 1939)

significantly lower than that for the 1st or the 2nd drawing. The next six months' storage produced the opposite effect, the lea strength increasing by a significant amount. It should be noted, however, that in spite of this increase, the value of lea strength for the 4th drawing remained significantly less than that for the 1st or the 2nd drawing. Further storage produced steady decline in the strength. Though for each period of six months the value was not significantly less than the previous value, yet the value for the 6th drawing was significantly lower than that of the 4th drawing, showing that, as in the case of the 1st year of storage, this effect became quite pronounced after storage for another year.

The single-thread strength results also show in general the same type of variations as the lea strength values, with the difference that value for the 4th drawing shows a decrease instead of an increase, while the value for the sixth drawing registers an increase instead of a fall as compared with the previous value in either case. It should, however, be noted that the difference between the values for the 3rd and the 4th drawings is insignificant, while that between the 5th and the 6th drawings is just on the border line of significance.

As against the yarn strength, the extension percentage shows a very mild tendency to increase with lapse of time of storage. The value for the 2nd drawing is significantly higher than that for the first, but no further significant increase takes place till the 5th drawing, which, however, is followed by a fall—not significant—in the last drawing. The curve for this property appears very much like a mirror image of the curve for single-thread strength.

It will be noticed from Table IV that the sum of squares for storage periods for each of the three properties has been split up into linear component and parabolic component of second degree. The contribution of the linear component in each case is relatively large, showing that progressive change has taken place in these properties with the lengthening of storage period, but the parabolic component shows that this progressive change is superimposed upon by the effect of other factors, the most important among them being humidity.

The downward trend of both the lea strength and the single-thread strength may be attributed to the progressive decay set in by fungi and bacteria, while the occasional rise must be due to the additional effect of atmospheric conditions, especially humidity. As may be seen from the values of mean relative humidity shown in the last column of Table III, the higher value of lea strength in the 4th drawing is probably due to the higher relative humidity prevailing during the preceding six monthly period. In the sixth period, however, it would appear that the improvement due to higher relative humidity is affected by the adverse effect of storage over a long period. Thus during first year when the bale may have lost an appreciable fraction of its moisture, there is a considerable decrease in lea strength, but during the 2nd year of storage, when it became, so to say, stabilized to conditions in Bombay, the fluctuations are less pronounced. During all this time, however, the fungi were at work, causing a slow decrease in strength underlying the observed fluctuations.

The opposite tendency of single-thread strength and extension percentages shown by results is noteworthy. Quite high single-thread strength in the same cotton is associated with high extension percentage though this cannot be said to be a general rule. In the present case, the upward mild tendency in extension percentage suggests that the fibres weakened in places by fungi may stretch slightly more before breaking, though the breaking strength may be somewhat less than or equal to that of the undamaged fibres.

The Congo Red Test. The results of this test are given in Table V. The percentage values shown here are based on the examination of 300 fibres for each sample. A perusal of this table reveals a gradual fall in the percentage of undamaged hairs up to the 4th drawing after which it remains more or less constant. The percentage of fibres suffering from fungal damage shows a corresponding increase, while the fibres with mechanical damage show a sudden increase in the second drawing. The only mechanical stress to which the bale was subjected during this period was a transit to the pressing factory, cutting open of the hoops, re-pressing of the bale and its journey back to the Laboratory. If these operations could cause appreciable mechanical damage then it would be reasonable to expect a similar increase after every subsequent drawing. Since the number of mechanically injured fibres did not show any such increase after the second drawing, it is highly likely that these damaged fibres were present in the outer portions of the bale, which were well mixed with the interior layers after the first re-pressing of the bale. The fall in the number of mechanically damaged fibres noticed from 3rd drawing onwards is due to the masking effect of fungal growths which are particularly heavy on injured spots.

It may be mentioned here that the fibres of B. D. 8 showing fungal damage included quite a large proportion of internally corroded fibres, a type of deterioration described by Gulati in 1936. As such deterioration usually occurs at the ends it is probable that it was the cause of shortening of fibre length.

The causes responsible for the inhibition of damage due to fungi after the 4th drawing are not quite clear. It may be due to the want of suitable conditions for further development of fungi. The chief among them is moisture which must be present in a sufficient quantity for the growth of micro-organisms [Bright, Morris and Summers, 1924; and Galloway & Burgess, 1937]. The lower limit of moisture content below which deterioration due to micro-organisms is retarded, is 9 per cent according to Flemming and Thaysen [1920]. It is highly likely that the moisture content of the bale was brought down below this limit by the repeated opening and re-pressing of the bale, especially as these drawings were made during the comparatively warm and dry months of April and October. Furthermore, the repeated ventilation of the cotton every six months may have also contributed to the inhibition of fungal growth. Burns [1925] found that ventilation of cotton during storage was favourable for the suppression of decay. Alternatively, as observed by Denham [1922], the initial infections may have died out in course of time and did not get replaced by fresh ones. This point is discussed in some detail in the following section:

Isolation of fungi found on B. D. 8. As reported in an earlier publication, 18 different fungi, some of them being known to possess the power of decomposing cellulose, were isolated from Broach Palej cotton by Gulati [1937]. A similar attempt was also made to isolate fungi from Broach Deshi 8. The tests were made on two occasions, namely on the first and the last drawings so that it may be possible to compare the infections at the beginning and at the end of the storage.

Two media—Nutrient agar and Czapek's solution agar were employed in these tests, and the results obtained are summarized in Table VI.

Five different genera of fungi were isolated from this cotton. It is interesting to note that four of these were also present on Broach Palej, while the fifth was noticed only on this cotton.

From the data in Table VI it will be noticed that the number of colonies on Czapek's solution agar was considerably higher in the first than in the last drawing but on Nutrient agar the number of colonies is small on both occasions. Out

TABLE V

Results of Congo Red Damage test

Drawing No.	Per cent un-damaged fibres	Per cent mechanically damaged fibres				Per cent fibres damaged by fungi				Total
		Slight	Moderate	Extensive	Total	Slight	Moderate	Extensive	Total	
1	75	4	..	..	4	12	9	..	21	100
2	63	11	1	..	12	24	1	..	25	100
3	51	10	1	..	11	17	20	1	38	100
4	45	9	1	..	10	31	13	1	45	100
5	50	7	2	1	10	24	15	1	40	100
6	46	7	2	..	9	19	25	1	45	100

TABLE VI

Fungi from B.D. 8

No.	From first drawing				From sixth drawing			
	Date of inoculation	Date of examination	No. of colonies	Identification	Date of inoculation	Date of examination	No. of colonies	Identification
				Czapek's medium				
1	1-5-37	4-5-37	84	*Aspergillus* sp. and *Phycomyces*	9-10-40	15-10-40	1	*Cladosporium* sp.
2	1-5-37	4-5-37	72	Ditto	9-10-40	15-10-40	1	*Aspergillus* sp.
3	1-5-37	4-5-37	42	*Phycomyces* and *Penicillium* sp.				
				Nutrient agar				
1	26-4-37	30-4-37	2	*Mucor hygrophilus**	14-9-40	21-9-40	3	*Aspergillus niger* and *Penicillium* sp.
2	26-4-37	30-4-37	12	*Mucor hygrophilus* and *Aspergillus* sp. and Bacteria	14-9-40	21-9-40	2	*Penicillium* sp.
3	26-4-37	30-4-37	1	*Basidiobolus* sp.*				

* As the genus *Basidiobolus* and the species *Mucor hygrophilus* have not been recorded previously from India their identification should be regarded as tentative and subject to confirmation

of the five different genera observed in the first drawing only two, namely *Aspergillus* and *Penicillium*, are represented in the last drawing, while three genera, namely *Phycomyces*, *Mucor* and *Basidiobolus*, noted in the first drawing failed to make their appearance in the final drawing, indicating that their infections were dead. Only one genus, *Cladosporium*, appears to have taken their place, according to Thaysen and Bunker [1927] the three genera noted in the 6th drawing have positive cellulose decomposing powers. Hence, the alternate explanation suggested in the preceding section, that inhibition of damage might be due to replacement of old by new and harmless infection, does not find much support from the data on isolation of fungi. The ability to grow on suitable media even after 2½ years' storage shows that at least two genera, *Aspergillus* and *Penicillium*, survived the repeated opening and re-pressing of the bale, though it is probable that their growth was arrested owing to insufficient moisture in the interior of the bale.

II. *Storage of small samples*

This part is further subdivided into two parts dealing with two types of storage, viz. (*A*) storage at different humidities at the room temperature, and (*B*) storage at different humidities at 92°F. The results of the studies under these two conditions of storages are discussed below:

Storage at room temperature. This part deals with the storage of cotton in different humidities at the room temperature. Both Broach Palej and B. D. 8 were stored at 60, 75 and 90 per cent R.H. and saturated humidity for two years, i.e. from April 1938 to March 1940. The effect of storage on bundle strength of fibres, incidence of fungal infection and shade of cotton was studied and the results are summarized in Tables VII—IX. Tables VII and VIII, containing results of bundle strength and incidence of infection for the above-mentioned humidities, also include results for 92, 93, 94 and 95 per cent R.H. together with the effect of cutting out light at the last-named humidity. It may be mentioned here that actual humidities above 90 per cent did not necessarily agree with the values expected from the recommended strengths of calcium chloride solutions. Thus, the humidity mentioned here as 92 per cent was obtained from $CaCl_2$ solution meant for 95 per cent R.H. and the so-called saturated humidity never yielded, as tested with a dew-point hygrometer, a value higher than 95 per cent R.H. The results of the three types of tests mentioned above will now be discussed separately.

TABLE VII

Strength test results of stored samples (*in oz. for a bundle* of* 100 *fibres*)

Months of storage	Broach Palej at R. H.				Broach Deshi 8 at R. H.							
	60 per cent	75 per cent	90 per cent	Saturated	60 per cent	75 per cent	90 per cent	92 per cent	93 per cent	94 per cent Saturated over $CaCl_2$ solution	Saturated over water	Saturated over water in dark
1 . .	8·18	7·00	7·68	6·67	10·06	10·01	10·00	9·19	9·19	9·19	9·56	9·19
2 . .	6·50	7·70	6·90	2·75	9·47	9·57	10·39	8·92	7·97	2·14	4·92	7·14
3 . .	7·69	7·72	7·00	2·17	9·67	10·26	10·01	9·73	4·28	2·29	2·25	4·04
4 . .	8·70	7·59	7·53	1·04	8·19	10·53	7·94	9·24	3·96	1·61	1·50	2·15
5 . .	7·87	7·70	5·33	0·11	11·71	10·11	9·34	8·15	3·28	0·61	0·05	2·91
6 . .	6·29	6·09	6·54	..	8·35	10·44	10·67	6·60	2·36	..	..	1·73
7 . .	6·75	6·11	7·54	..	9·42	11·77	8·66	5·59	0·52	..	..	2·40
8 . .	7·73	8·85	8·57	..	9·39	11·15	9·78	4·35	..	..	..	2·49
9 . .	7·56	6·81	8·23	..	8·72	10·00	9·29	4·29	..	..	..	1·40
10 . .	6·65	6·85	7·27	..	9·77	11·72	9·12	0·41	..	..	..	0·81
11 . .	7·89	8·01	7·10	..	10·19	9·04	11·51	..	..	..	..	..
12 . .	7·89	6·92	8·16	..	11·36	10·05	11·57	..	..	..	..	..
13 . .	7·29	7·89	7·78	..	7·24	9·61	10·28	..	..	..	..	..
14 . .	7·50	7·35	6·46	..	9·15	10·52	9·24	..	..	..	..	..
15 . .	7·55	6·79	7·43	..	7·71	12·23	10·12	..	..	..	..	..
16 . .	8·72	8·62	7·39	..	11·42	12·09	9·45	..	..	..	..	..
17 . .	7·20	5·73	7·28	..	12·43	11·24	9·34	..	..	..	..	..
18 . .	8·45	7·41	6·68	..	9·74	10·10	9·93	..	..	..	..	..
19 . .	7·88	7·42	6·57	..	9·95	10·52	10·80	..	..	..	..	..
20 . .	7·25	8·10	6·39	..	10·83	10·55	10·99	..	..	..	..	..
21 . .	7·75	8·57	8·37	..	13·77	11·50	11·65	..	..	..	..	..
22 . .	6·42	7·87	7·88	..	11·21	10·70	10·78	..	..	..	..	..
23 . .	6·48	8·66	6·56	..	9·29	10·43	10·81	..	..	..	..	..
24 . .	6·84	7·67	7·47	..	9·75	9·50	10·06	..	..	..	..	..
Total .	178·94	179·07	174·11	..	238·79	253·64	241·73	..	..	..	..	..
Mean .	7·46	7·46	7·25	..	9·95	10·57	10·07	..	..	..	..	..
					S. E.=0·932							

* Each value in this table is a mean of 20 bundles

S. E. refers to individual entries in the columns under 60, 75 and 90 per cent R. H. for both cottons

Bundle strength. The strength test results show that neither cotton suffers any appreciable loss in strength at humidities below 90 per cent, while signs of quick tendering are noticeable at humidities above 90 per cent. It is to be noted that both Broach Palej and Broach Deshi 8 decay completely in four to five months storage at saturated humidity. It would appear from these results that there is a critical limit just above 90 per cent R.H., and that whereas below this critical

limit these cottons can stay practically without any deterioration in strength for two years, above this limit they deteriorate rapidly and lose strength completely within four to five months. In order to fix, if possible, this critical limit, the effect of higher humidities, i.e. those lying between 90 per cent and the saturated humidity, was studied with Broach Deshi 8 cotton. The results obtained show that tendering of cotton sets in at humidities just above 90 per cent R.H. but that the rate of tendering increases with the humidity. Thus, cotton kept at 92 per cent R.H. took the longest, while that at 94 per cent R.H. took the shortest time to reach a similar stage of tendering. The effect of keeping the cotton in dark at saturated humidity was to slow down the rate of degradation, as is indicated by the period of nine months taken by it to reach the final stage of degradation as against a period of only five months in ordinary light. The important auxiliary part played by light in degrading cotton cellulose is well shown by these results.

It is interesting to note that fungal growths were more intense, widespread and rapid at saturated humidity and 94 per cent R.H. than at 93 per cent R.H., and more so at the latter humidity than at 92 per cent R.H. This correspondence of heavier fungal growth with greater and quicker loss in strength shows that degradation of cotton is almost entirely due to fungal growths. In order to verify this point, samples of the same cotton (B.D. 8) were sterilized in concentrated and 5 per cent formalin, dried to drive away the vapour and stored at saturated humidity. It is noteworthy that these samples did not show any loss in strength for 10 months of storage as shown by the values given below:

Date of test	Bundle strength for 100 fibres in oz.	
	Strong formalin	5 per cent formalin
1. 11-7-1939 . . .	10·24	11·33
2. 11-8-1939 . . .	10·62	11·07
3. 15-9-1939 . . .	11·06	11·84
4. 11-10-1939 . . .	9·94	11·63
5. 8-11-1939 . . .	10·68	12·27
6. 8-12-1939 . . .	9·79	10·17
7. 8-1-1940 . . .	10·10	10·93
8. 7-2-1940 . . .	11·19	..
9. 6-3-1940 . . .	10·24	..
10. 9-4-1940 . . .	9·97	10·38

Thus, immunity from degradation under very adverse conditions can be achieved by first effectively sterilizing a cotton which would kill the fungi and bacteria responsible for this degradation.

TABLE VIII

Incidence of infection with micro-organisms in stored samples (percentages)

Months of storage	Broach Palej at R. H.				Broach Deshi 8 at R. H.							
	60 per cent	75 per cent	90 per cent	Saturated	60 per cent	75 per cent	90 per cent	92 per cent	93 per cent	Saturated over $CaCl_2$ solution	Saturated over water	Saturated over water in dark
1 . .	50	60	58	57	40	47	47	66	66	66	47	66
2 . .	48	46	53	86	55	47	39	76	79	83	63	77
3 . .	59	65	64	93	58	61	62	76	72	91	92	98
4 . .	56	55	65	96	50	64	53	71	87	97	95	98
5 . .	55	63	72	99	51	58	51	67	97	95	99	97
6 . .	56	62	68	..	51	56	60	84	96	..	..	98
7 . .	63	54	72	..	55	59	58	76	97	..	..	96
8 . .	59	61	65	..	54	48	53	87	..	..	..	95
9 . .	58	61	63	..	56	56	61	95	..	..	..	100
10 . .	61	71	68	..	57	62	62	..	..	..	..	..
11 . .	66	70	68	..	51	57	54	..	..	..	..	..
12 . .	56	65	66	..	45	56	59	..	..	..	..	..
13 . .	60	60	73	..	52	45	51	..	..	..	..	..
14 . .	65	66	65	..	50	58	61	..	..	..	..	..
15 . .	61	77	71	..	61	62	53	..	..	..	..	..
16 . .	61	72	75	..	61	58	71	..	..	..	..	..
17 . .	62	76	70	..	57	70	61	..	..	..	..	..
18 . .	62	67	73	..	63	54	58	..	..	..	..	..
19 . .	68	78	73	..	63	63	62	..	..	..	..	..
20 . .	75	73	71	..	61	58	68	..	..	..	..	..
21 . .	74	74	70	..	49	63	64	..	..	..	..	..
22 . .	75	73	72	..	65	66	63	..	..	..	..	..
23 . .	56	71	63	..	62	53	49	..	..	..	..	..
24 . .	71	69	66	..	52	67	56	..	..	..	..	..
Total .	1479	1589	1624	..	1319	1388	1376	..	..	..	..	..
Mean .	61·6	66·2	67·7	..	55·0	57·8	57·3	..	..	..	..	..
					S. E.=4·87							

S. E. was obtained for data under 60, 75 and 90 per cent R. H. only for both cottons together and refers to single entries in the respective columns

Incidence of fungal infection. The use of cotton blue dissolved in lactophenol, as described earlier in this paper, led easily to the detection of fibres infected with micro-organisms from all the samples stored at different humidities. The results are presented in Table VIII as percentages based on the examination of about 500 fibres in each case. An examination of the results shows a steady increase in the percentage of infected fibres at all humidities higher than 60 per cent R.H. It also shows that the increase in the number of infected fibres is more appreciable at higher than at lower humidities. At humidities higher than 90 per cent, the increase may be described as rapid, which agrees well with the loss in strength shown in Table VII.

Analysis of variance applied to the data obtained for storage at 60, 75 and 90 per cent R.H. gave the following results:

This analysis leads to the following conclusions:

(*i*) The infection of Broach Deshi 8 is significantly lower than that of Broach Palej.

TABLE VIII (*a*)

Analysis of variance (incidence of infection)

Source	D.F.	Sum of squares	Mean squares
Between cottons . .	1	2575·56	2575·56
Between storage periods	23	3711·61	161·37
Between humidities .	2	509·54	254·77
Interaction :			
Cotton × storage . .	23	448·60	19·50
Cotton × humidity .	2	80·80	40·40
Humidity × storage .	46	1016·79	22·10
Residual . . .	46	1089·54	23·69
Storage periods :			
Linear component .	1	593·59	593·59**
Parabolic component of 2nd degree .	1	203·83	203·83**
Parabolic component of 3rd degree .	1	3·53	3·53
Deviation . .	20	2910·66	145·53**
Total .	23	3711·61	

**Denotes significance at 1 per cent level

TABLE IX

Shade measur_ments of two cottons stored at four different humidities

Storage period (months)	Broach Palej				Broach Deshi 8			
	60 per cent	75 per cent	90 per cent	Saturated	60 per cent	75 per cent	90 per cent	Saturated
1	0·80	0·78	0·89	0·81	0·85	0·82	0·81	0·91
2	0·79	0·75	0·82	0·51	0·85	0·83	0·79	0·61
3	0·78	0·75	0·82	0·46	0·85	0·83	0·79	0·51
4	0·76	0·75	0·85	0·46	0·85	0·84	0·81	0·49
5	0·79	0·75	0·81	0·46	0·86	0·84	0·81	0·49
6	0·78	0·75	0·73	0·43	0·86	0·86	0·76	0·47
7	0·79	0·75	0·72	0·44	0·81	0·84	0·79	0·45
8	0·79	0·76	0·72	0·44	0·83	0·85	0·79	0·46
9	0·77	0·73	0·70	0·42	0·84	0·81	0·75	0·46
10	0·76	0·77	0·69	0·38	0·82	0·79	0·73	0·43
11	0·75	0·75	0·68	0·39	0·79	0·77	0·70	0·39
12	0·77	0·76	0·67	0·41	0·79	0·79	0·71	0·43
13	0·77	0·83	0·68	0·42	0·80	0·77	0·68	0·42
14	0·80	0·78	0·68	0·40	0·82	0·84	0·74	0·44
15	0·79	0·78	0·65	0·42	0·85	0·80	0·67	0·41
16	0·75	0·75	0·63	0·42	0·83	0·84	0·66	0·42
17	0·78	0·77	0·65	0·43	0·90	0·86	0·65	0·42
18	0·76	0·77	0·62	0·44	0·86	0·87	0·65	0·43
19	0·78	0·76	0·59	0·39	0·83	0·83	0·63	0·42
20	0·74	0·74	0·59	0·36	0·83	0·76	0·64	0·41
21	0·76	0·76	0·60	0·38	0·83	0·74	0·65	0·40
22	0·77	0·77	0·64	0·42	0·85	0·85	0·65	0·40
23	0·80	0·80	0·66	0·35	0·84	0·83	0·64	0·41
24	0·78	0·78	0·64	0·43	0·82	0·82	0·64	0·40
Total .	18·61	18·34	16·73	10·47	20·06	19·67	17·14	11·08
Mean . .	0·775	0·764	0·697	0·436	0·836	0·819	0·714	0·462

S. E. of single entry υ·02536

(*ii*) The critical difference between the means of storage periods is 7·6 for $P=0\cdot01$. Judging on its basis, a significant increase is noticed only after 14 months, which persists, with minor fluctuations, till the 24th month.

On splitting the variance for storage periods into its linear and parabolic components, we find the linear component is highly significant showing a progressive change with storage. However, the part contributed by the deviations is still large and significant, indicating the influence of random factors.

(*iii*) The mean value for storage at 60 per cent R.H. is significantly lower than that for 75 per cent R.H. or 90 per cent R.H. The mean value for storage at 90 per cent R.H. is not significantly different from that for 75 per cent R.H., the critical difference being 2·7.

(*iv*) The interactions are all found to be non-significant.

It will be observed from the preceding account that growth of fungi is possible at 75 per cent R.H. and higher humidities. This observation confirms the work of Galloway [1938], Chowdhury [1937], and Prindle [1937] who observed that spores of some fungi can germinate at 75, 90 and 82 per cent R.H., respectively, which according to them were the lowest limits of humidity for such growths. Their effect, however, in weakening the fibre does not become appreciable at humidities below 90 per cent R.H.

Shade measurements. The results given in Table IX were obtained with the photo-electiric-cell device designed for this purpose. On account of the completeness of these data in respect of two cottons, four humidities and 24 monthly readings, they were subjected to analysis of variance as shown in Table IX (*a*).

The following conclusions are drawn from this analysis :

(*i*) B.D. 8 is slightly whiter than Broach Palej in the initial stage as will be seen from the mean of the four readings for either cotton which is 0·85 for B.D. 8 and 0·82 for Broach Palej.

(*ii*) In both cottons the shade remains unaffected at 60 per cent R.H. and 75 per cent R.H. up to the end of this period of storage, but at 90 per cent R.H. and the saturated humidity, the shade of both cottons is reduced gradually—the fall being noticeable in the 6th month for 90 per cent R.H. and in the second month at saturated humidity. The fall in shade at saturated humidity appears to stop after the 10th month in both cottons, while for 90 per cent R.H. it continues almost to the end of the storage period.

This effect is also observed by splitting the variance, where the linear component is by far the largest. Although the contribution of parabolic components and the deviations is still significant, the major part of the effect is seen to be due to progressive change with the storage period.

TABLE IX (*a*)

Analysis of variance (shade measurements)

Source	Degrees of freedom	Sum of squares	Mean squares
Between cottons	1	0·075208	0·075208
Between storage periods	23	0·324673	0·014116
Between humidities	3	3·939706	1·313235
Interaction :			
Cotton × storage	23	0·013017	0·000566
Cotton × humidity	3	0·016701	0·005567
Storage × humidity	69	0·375569	0·005443
Residual	69	0·044374	0·000643
Total	191	4·789248	
Storage periods :			
Linear component	1	0·19696	0·19696**
Parabolic component of 2nd degree	1	0·06041	0·06041**
Parabolic component of 3rd degree	1	0·01684	0·01684**
Deviation	20	0·05046	0·00252**
Total	23	0·32467	

** Denotes significance at 1 per cent level

(*iii*) The two cottons appear to behave in a similar manner with respect to period of storage, as shown by the non-significance of the interaction between cotton × storage.

(*iv*) The critical difference for the mean values after storage for two years is 0·0198 for either cotton. Thus, whereas the mean values for 60 and 75 per cent R.H. do not vary significantly from one another, they are significantly higher than those for 90 per cent R.H. and saturated humidity, which also differ significantly between themselves.

(*v*) The fact that the interaction between humidity and storage is significant shows that the effect of these two factors is not similar. This would be clear from examining the values for storage at 90 per cent R.H. and at saturated humidity. The former go on decreasing steadily till the end of storage period, while the latter remain practically unchanged after 10 months. Similarly, the differential response of cottons to humidity, as indicated by the significant value of interaction between them shows that the two cottons did not behave alike in this respect. This would also be seen from the fairly big fall at 90 per cent R.H. for Broach Palej in the second month, while a fall of similar magnitude for the B.D. 8 takes place only in the 6th month.

We may now recapitulate the results by observing that out of the three kinds of tests employed to study deterioration in cotton on storage under different humidities, the bundle strength of the fibres was affected only at humidities above 90 per cent R.H., the shade was affected even for storage at 90 per cent R.H. and above, while the percentage of infected fibres was found to increase even at 75 per cent R.H. It may be mentioned here that the samples which were sealed in dishes for measurement of shade were also tested for bundle strength after two years of storage. The results obtained are given in Table X.

TABLE X

Bundle strength for 100 fibres*

		Broach Deshi 8	Broach Palej
		oz.	oz.
Initial strength . . .		10·25	7·70
Strength after storage for two years—			
at 60 per cent R.H.	Top	10·35	7·88
	Bottom	10·82	7·99
at 75 per cent R.H.	Top	9·55	7·31
	Bottom	8·23	6·70
at 90 per cent R.H.	Top	4·46	1·54
	Bottom	1·90	0·20

at saturated R.H.: Samples could not be tested because they were decayed completely

*Each value in the table is a mean of tests on 20 bundles

It will be noticed that loss in strength of fibres was noticeable even at 75 per cent R.H. especially for the lower half of the sample. Since the behaviour of strength is somewhat dissimilar in the two types of storages, i.e. in desiccators and petri dishes, it would be instructive to examine the conditions of storage in these two cases. The chief differences in conditions of storage were as follows:

(*a*) In the desiccators the cotton was placed in a loose condition, while in the dishes it was packed fairly hard between the glass top and the perforated porcelain disc at the bottom.

(*b*) The desiccators provided contact with air all round the sample, while in the dishes such contact was available only through the perforated disc at the bottom.

(*c*) The cotton in the desiccator was disturbed every month when a small sample was taken out for strength and infection tests, while such disturbance and change of air did not occur for the sample in petri dishes.

(*d*) The samples in the dishes were exposed to light from a 100 watt. bulb for about an hour every month, while the samples in desiccators were subjected to no such exposure to light.

The above-named differences resolve down to the effects of exposure to light, aeration and disturbance. It is doubtful if exposure to light from an electric bulb for such short periods would have any marked effect in promoting degradation in the petri dishes. In any case, the effect would be more noticeable on the upper than on the lower half of the sample, which is just the opposite of what is actually observed by us. This leaves the other two factors, namely, aeration and disturbance for consideration. The first factor, aeration, provides oxygen for the fungi, it also prevents accumulation of moisture in any one place in the stored cotton, while the monthly disturbance would further aid in stopping the accumulation of moisture. Thus the absence of both these factors would be helpful in providing conditions favourable to fungal growth. Thus, the deterioration in strength of cotton stored at humidities below 90 per cent R.H., when it was not disturbed for nearly two years may be ascribed principally to the accumulation of moisture in cotton and its effect upon fungal growth. In order to test this explanation the moisture content of cotton stored without any disturbance for six months was compared with that obtained for cotton stored for three days and it was found, as shown below, that the former values were definitely higher both for 75 and 90 per cent R.H.

Storage at	B.D. 8 Cotton moisture regain per cent	
	Sample after 3 days' storage	Undisturbed sample after 6 months' storage
75 per cent R.H. . .	9·39	13·39
90 per cent R.H. . .	14·4	15·70

Storage at 92°F. These studies were made on B.D. 8 cotton, which was stored in desiccators at 92°F. and 60, 70, 80, 90 and over 90 per cent R.H. without the use of any salt solutions by the method described below. The selected temperature of 92°F. is slightly higher than that occurring usually in Bombay inside a room. Before starting the experiment 25 gm. of the cotton was weighed for each humidity and along with the open desiccator, lid, etc. was conditioned at the required relative humidity and 92°F. for three hours inside a room in which both these factors

could be maintained constant. The sample was then placed in the desiccator and sealed in it, and the desiccator was transferred to an incubator maintained at 92° F.

Small samples were drawn from these desiccators at their respective humidities and 92°F. temperature for strength and infection tests every month for $1\frac{1}{2}$ years. On each occasion the main sample was conditioned as in the beginning for one hour before re-sealing it. The results of the tests carried out on these samples are given in Table XI.

TABLE XI

Results of strength and infection tests on B.D.8 stored at different humidities and 92°F. temperature

Months of storage	Strength in oz.					Incidence of infection per cent				
	R.H. 60 per cent	70 per cent	80 per cent	90 per cent	Over 90 per cent	60 per cent	70 per cent	80 per cent	90 per cent	Over 90 per cent
1 . . .	8·88	10·50	8·85	10·44	9·79	60	64	63	65	61
2 . . .	10·44	10·62	8·73	9·90	10·65	55	59	54	55	64
3 . . .	8·46	8·84	9·71	8·89	10·90	64	59	64	65	65
4 . . .	10·40	11·01	10·14	9·13	10·03	54	59	60	63	65
5 . . .	9·41	7·56	9·07	9·63	10·54	55	60	56	56	59
6 . . .	10·13	9·76	8·65	8·70	8·71	51	55	59	68	68
7 . . .	11·33	8·41	9·24	10·37	8·81	47	54	66	65	69
8 . . .	8·98	7·83	6·83	9·09	9·59	56	51	69	70	73
9 . . .	8·79	10·74	9·10	9·07	8·93	65	57	58	59	62
10 . . .	9·60	11·02	10·67	10·78	9·84	60	56	63	61	77
11 . . .	10·32	10·61	9·45	10·36	9·24	55	64	64	64	68
12 . . .	10·85	12·16	9·81	10·59	8·88	49	52	50	67	63
13 . . .	10·23	8·02	8·49	8·62	9·86	47	55	53	66	65
14 . . .	11·82	9·09	10·18	10·98	10·83	55	57	60	63	68
15 . . .	11·09	10·94	10·96	10·06	6·92	62	63	63	70	83
16 . . .	10·04	10·57	10·29	11·09	10·08	59	70	67	69	80
17 . . .	8·40	9·04	8·34	8·82	9·65	64	62	70	50	65
18 . . .	11·14	11·22	9·97	8·81	11·29	58	55	55	52	60
Total . .	180·31	177·94	168·48	175·33	174·54	1016	1052	1094	1128	1215
Mean . .	10·02	9·89	9·36	9·74	9·70	56·4	58·4	60·8	62·7	67·5

Analysis of variance

—		Strength			Infection	
		D. F.	S. S.	M. S.	S. S.	M. S.
Between storage periods		17	34·1454	2·00855**	1176·5	69·205**
Between humidities		4	4·4017	1·100425	1300·0	325·00***
Residual		68	62·2649	0·91566	1690·0	24·85
Storage	Deterioration . .	1	2·03771	2·03771	31·788	31·788
	Slow changes . .	2	3·180635	1·590318	70·755	35·379
	Deviations . . .	14	28·927055	2·066218*	1073·953	76·711*
Humidity	Linear component .	1	..	..	1248·2	1248·2***
	Deviations . . .	3	..	..	51·8	17·3

* Indicates significance at 5 per cent level
** " " at 1 " " "
*** " " at ·1 " " "

The application of analysis of variance to the data given in Table XI showed that the variance ratio for storage periods is significant at 1 per cent point both for the strength and the infection results while it is significant for humidities only for the infection results. In order to investigate whether this significance of the variance ratio is due to deterioration or slow changes or to the action of some random causes, the sum of squares was further split up, and it was found that both the components for deterioration and slow change are non-significant, in the case of strength as well as incidence of infection, showing that the significance for the average effect is due to some random causes. In order to study this point further, the data for each humidity were analyzed separately by fitting third degree polynomials. It was found that the mean squares both for deterioration and slow change are non-significant in every case, as will be seen from the following table.

MEAN SQUARE

—	D. F.	Strength					Infection				
		R. H. percentage					R. H. percentage				
		60	70	80	90	over 90	60	70	80	90	over 90
Deterioration	1	1·9056	0·7937	1·3369	0·0890	0·2850	4·956	3·302	3·302	7·934	91·456
Slow changes	2	0·1867	1·2729	0·2502	1·9632	1·5590	38·109	56·995	3·086	103·261	42·164
Residual	14	1·1238	1·9761	1·0582	0·6124	1·0535	32·091	19·797	38·260	28·825	43·051

This analysis shows that there is no evidence of progressive decrease in strength or increase in infection or other slow changes during $1\frac{1}{2}$ years' storage period at 92° F.

As regards the effect of humidity on incidence of infection which is found to be significant, it may be pointed out that the deteriorating effect of this increase is not reflected by the strength results.

These results indicated the importance of temperature as a controlling factor for fungal growth. In order to verify this point the sample, which had been stored over 90 per cent R.H. in the incubator, was stored for a further period of three months at room temperature and was subjected to the tests. It was found to be full of fungal spores and gave out musty smell; its strength fell from 11·29 oz. to 2·38 oz. and the infection percentage rose to 87 from 67, indicating the temperature 92°F. or 33·3°C. had inhibited fungal growth which grew freely after the sample was transferred to room temperature. As pointed out by Galloway and Burgess [1937] the optimum temperature for a majority of fungi lies in the region of 25°C., while the inhibiting temperature is generally said to be 40°C. In the present case the success of a lower temperature in preventing degradation of cellulose is evidently due to the absence of any water in the desiccator which prevents the accumulation of moisture on the fibre during the period of storage. Under such conditions, it would appear that a lower temperature, than is generally regarded necessary, may be effective in preventing the decay of cellulose due to fungal growth. Here again we notice the advantage of storing cotton in a dry place where no water is available near at hand to permit its accumulation on it thereby providing condition favourable to fungal growth.

III. *Damage due to localized watering*

We saw in part II that if the humidification is uniform so that there is no accumulation of moisture in any one place, cotton can be stored at fairly high humidities, reaching up to 90 per cent R.H. for about two years without suffering appreciably in fibre strength or shade. When, however, the humidity goes up above 90 per cent R.H., deterioration sets in resulting in loss of strength and increase in the number of infected fibres. It is known that a certain amount of deterioration sometimes takes place in baled cotton even when the bales are stored at humidities below 90 per cent R.H. These two observations would appear to conflict with one another, but the clue to this apparent inconsistency lies in the observations described earlier which showed that, when the conditions of storage are conducive to the accumulation of moisture in any one place, the percentage of infected fibres increases steadily resulting in loss of strength and colour. These observations led us, in view of the practical importance of the question to study in some detail the effect of localized watering on different cottons stored at different humidities.

The success of the experiment depended upon preventing the evaporation of water added to the cotton so that, in that region at least, moisture corresponding to humidities higher than 92 per cent could be maintained for a part of the period of storage. This was accomplished by preparing two pads from each cotton, one of which was wetted in parts, while the other was used for covering it. The effects of three conditions of storage, namely dry, 60 per cent R.H. and 90 per cent R.H. were studied in this investigation, which was carried out on 11 different cottons. It will be remebered that in each case 8 c.c. of water were added to 30 gm. of cotton, being applied to four different regions.

TABLE XII

Effects of localized watering on strength and incidence of infection

Cotton	Botanical species and staple grades	Initial strength (oz.)	Strength after storage for 3 weeks at			Initial	Infection after storage for 3 weeks at		
			Dry atmosphere	R. H. 60 per cent	R.H. 90 per cent	Infection per cent	Dry atmosphere	R. H. 60 per cent	R. H. 90 per cent
Broach Deshi 8 .	*Gossypium herbaceum Var. frutescens* (medium)	11·44	9·55	9·31	8·86	54	62	68	70
Verum 262 Nag.	*G. arboreum, Var. neglectum, forma bengalensis* (medium)	8·07	7·26	6·36	3·79	68	75	75	79
P. A. 289F .	*G. hirsutum* (long) .	7·66	7·31	6·54	1·42	54	66	70	83
Cambodia Co 2	,, ,, .	6·18	5·92	4·68	3·81	67	71	83	87
P. A. 4F 98 .	,, (medium) .	8·01	7·17	6·90	1·77	62	67	75	78
Sindh Sudhar .	,, (long) .	8·87	8·79	7·89	2·79	57	60	60	80
Karunganni C7 .	*G. arboreum Var. neglectum, forma indicum* (medium)	9·49	9·32	8·15	3·71	53	60	73	75
Surat 1027 A.L.F.	*G. herbaceum, Var. frutescens* (long)	7·40	6·41	6·58	2·42	59	74	86	90
Jayawant .	,, ,, ,, .	9·63	9·09	8·03	3·29	63	62	71	81
Sindh N. R. .	*G. arboreum, Var. neglectum, forma bengalensis* (short)	9·85	9·66	9·85	3·71	48	59	63	70
Mollisoni . .	,, ,, ,, .	8·85	6·73	7·03	4·64	54	68	69	73
	Total . . .	95·45	87·21	81·32	40·21	639	724	793	866
	Mean . . .	8·677	7·928	7·393	3·655	58·1	65·8	72·1	78·7
	Per cent change over the initial	..	—9%	—15%	—58%	..	13%	24%	35%
			S. E.=0·9378				S. E.=3·93		

The results of the strength and infection tests, which were made on samples of these 11 cotton, stored at different humidities, are given in Table XII. These results bring out a number of interesting points. In the first place, it will be noticed that even when the cotton, to which a small quantity of water was added in small well-defined parts, was stored in a dry atmosphere, deterioration in strength and increase in the number of infected fibres took place in every case. This happened in spite of the fact that a certain amount of water must have evaporated and been absorbed by calcium chloride. It is clear, however, that some water must have been firmly held by the cotton to produce sufficient local humid conditions for the rapid multiplication of the fungi. The second noteworthy point is that, the magnitude of this deterioration, as shown either by the loss in fibre strength or increase in the number of infected fibres was greater when the cottons were stored at 60 and 90 per cent R.H. The mean values for the 11 cottons show that, as compared with the initial values, the change in strength is significant for storage at 60 and 90 per cent R.H., while the increase in percentage of infected fibres is significant even for storage in dry atmosphere. This is clearly brought out in Table XII (*a*) in which analysis of variance has been applied to the results for strength and percentage infection ; and it is shown that the effect of storage humidity is highly significant. The high significance of variance due to cottons may be due to differential response of cotton or it may be due to initial variation in respect of strength and infection. In order to

examine this point, the cottons were classified into their four botanical species, and instead of the actual values of strength and infection percentage at different humidities, the percentage changes from the initial values were taken and were considered. Table XIII shows the results of this examination.

TABLE XII (*a*)

Analysis of variance

Factors	Degrees of freedom	Strength		Infection	
		Sum of squares	Mean squares	Sum of squares	Mean squares
Cottons	10	73·005364	7·300536**	1273·05	127·30**
Storage humidities	3	164·834916	54·944972**	2561·91	853·97**
Residual (error)	30	26·384509	0·879484	462·59	15·42
Total	43	264·224789	..	4297·55	..

**Indicates significance at 1 per cent level

TABLE XIII

Varieties	No. of cottons	Mean percentage loss in strength				Mean percentage increase in infection			
		Dry	60 per cent R.H.	90 per cent R. H.	Total	Dry	60 per cent R. H.	90 per cent R. H.	Total
G. *herb. frutescens*	3	12	16	52	80	13	28	30	78
G. *arb. neg. indicum*	1	2	14	61	77	13	38	41	92
G. *arb. neg. bengalensis*	3	12	12	55	79	19	22	30	71
G. *hirsutum*	4	5	16	67	88	10	20	37	67

It will be seen that the loss in bundle strength on storage at 90 per cent R.H. is a little higher for *hirsutum* cottons than for the other varieties ; at 60 per cent R.H. it was lowest for *bengalensis* cottons ; while in the dry atmosphere the *indicum* cottons recorded the least loss, and the *frutescens* and *bengalensis* cottons registered the highest loss. Thus, no one class of cotton shows consistently high or low loss in strength at all humidities, but if we take the average for the three conditions of storage, the *hirsutum* cottons appear to be rather more and the *indicum* cotton rather less susceptible to deterioration in storage than the other two varieties. Flemming and Thaysen [1920] found that Indian cottons were more susceptible to mildew attack than the *hirsutum* cotton. This conclusion was supported by Thaysen and Bunker [1924] but later on in 1930 they stated that the evidence on this point was not conclusive. It must be admitted that the conclusion drawn above cannot be regarded conclusive not only because the number of cottons in each group is small, but also because the results for loss in strength are not directly proportional to the percentage increase in infection though the two generally run parallel to one another. The mean percentage increase of infection is highest for the *indicum* cottons and lowest for the *hirsutum* cottons. It should also be mentioned that within each group there are fairly large variations in the percentage loss of strength. Thus, while B.D. 8 registered a loss of only 23 per cent at 90 per cent R.H., the other two *herbaceum* cottons sustained losses of 67 and 61 per cent, respectively. The same feature is shown by the *hirsutum* and *bengalensis* cottons.

The reaction of the different cottons to storage after localized watering were also sutdied in respect of staple length. For this purpose 11 cottons were divided in three groups, namely long, medium and short, and the mean percentage loss in strength or increase in infection were worked out and are shown in Table XIV.

These results show same kind of variation as those obtained with the grouping of the cottons on the basis of their botanical species. Thus, for storage at 90 per cent R.H. the mean loss in strength is higher for the long staple cottons than for the other two groups, while at 60 per cent R.H., the short staple cottons still show the least loss in strength, but the medium staple cottons have moved up to the long staple group. In dry storage, however, the long staple cotton appears to have fared best. The increase in the incidence of infection is practically the same for the long and the

TABLE XIV

Cottons according to staple	Mean percentage loss in strength at			Total	Mean percentage increase in infection at			Total
	Dry atmosphere	60 per cent R. H.	90 per cent R. H.		Dry atmosphere	60 per cent R. H.	90 per cent R. H.	
Long	6	16	65	87	12	24	40	76
Medium. . . .	10	17	54	71	11·5	24	28	63·5
Short	13	10	53	76	24·5	29·5	40·5	94·5

short staple cotton at the highest humidity; but is rather more for the short stapled group at the two lower humidities. If we consider the means for all the three conditions of storage, we find that, in spite of a fairly high increase in the percentage of infection, the loss in strength was least for the short stapled cottons, while, with a smaller increase in the number of infected fibres, it was highest for the long stapled cottons. For the medium stapled cotton both the characters showed the least change.

We may draw the following important conclusions from the foregoing results:

(1) When water is sprayed, sprinkled or added to cotton, it always registers a loss in strength and shade in the damped regions, even if the cotton is subsequently stored in an absolutely dry atmosphere.

(2) The loss in strength increases as the humidity of the atmosphere in which the cotton is stored increases. From a mere trend in dry atmosphere it assumes a fairly large magnitude within a short period of three weeks' storage, at 90 per cent R.H. Furthermore, the loss in strength runs generally hand in hand with increase in fungal infection of fibres. The evil effects of watering cotton before pressing it into bales, on the ground that dry cotton would not press well, are clearly brought out by the results of these tests.

Having observed that addition of water, even in small quantities to cotton, leads to an appreciable rise in fungal growth and loss in strength, a search was made for a suitable antiseptic, which added to water may check or retard degradation due to fungal growth. In lookng out for such an antiseptic three considerations were primarily kept in view, namely (1) the antiseptic should not stain the cotton, (2) it should not be expensive, and (3) it should be effective in small doses. Keeping these points in view, Shirlan A and B, sodium pentachlorphenate, resorcin, chloramine T and formalin were tried, but only the last named, namely formalin, was found to fulfil these conditions. In order to find out the minimum strength of the solution which would be efficacious for checking the growth of fungi, various concentrations of formalin in distilled water were tried on B.D. 8 according to the technique followed for studying the effect of localized watering. The results of these observations are given in Table XV. In each case the sample was stored at 90 per cent R.H. so that the maximum effect may be registered, and the sample was stored for 21 days.

TABLE XV

Effect on strength and infection of B.D. 8 on watering with formalin dilutions

———	Strength	Infection
Initial	9·86 oz.	60 per cent
Strength after damping with water (distilled)	6·09 ,,	78 ,, ,,
Strength after damping with 5% formalin	9·10 ..	65 ,, ,,
Strength after damping with 2·5% formalin	10·52 ,,	58 ,, ,,
Strength after damping with 1% formalin	10·41 ,,	50 ,, ,,
Strength after damping with 0·5% formalin	10·31 ,,	57 ,, ,,
Strength after damping with 0·1% formalin	7·58 ,,	68 ,, ,,

These results show that dilutions below 0 5 per cent are not efficacious for preventing the degradation of cellulose by fungal growth. It should be mentioned that the above-mentioned dilutions were made from a bottle of commercial formalin which had a density of 17·2° Tw. corresponding to 27·8 per cent of pure formaldehyde in 100 gm. of solution. Generally, the trade sample is supposed to contain 36 per cent of pure formaldehyde by weight. With such a commercial produce, it is likely that a 0·1 per cent solution may prove effective. But, on the other hand, it must be remembered that these tests were made with distilled water, and that ordinary (tap, tank or well) water may itself be contaminated, and may, therefore, require a somewhat stronger concentration of formalin. Taking all factors into consideration, we imagine that solutions from 0·5 to 1 per cent of commercial formalin, of the correct concentration, would be required for the purpose mentioned above. We would like to make it quite clear at

his stage that we are not at all in favour of watering cotton in any shape or form whatever, and hat these tests have been carried out merely to nd out the conditions under which this process nay be rendered as harmless as possible, should it e found indispensable under certain special conlitions to raise the moisture content of cotton beore pressing and baling it. The pressing of cotton, n a dry state, with only its natural moisture ontent, is all the more important when the bales nave to be stored for any length of time at a port, as he tests have shown that degradation is more apid and intense at high storage humidities such s are likely to prevail near the sea.

Summary

The present paper gives an account of the effect f storage, under certain specified conditions, on ome of the important properties of Indian cottons. The conditions of storage were, (1) Bombay veather, (2) controlled humidities at room temperature and at a constant temperature, and (3) controlled humidity combined with watering of cotton. The characters studied were (1) fibretrength, (2) incidence of infection, and (3) shade f cotton. In addition, tests were also made on ibre length, fibre weight per inch and the spinning quality of the cotton. The following conclusions are drawn from the results :

(1) Broach Deshi 8, when stored in Bombay for 2½ years in the form of a bale, showed distinct signs of deterioration in quality, as indicated by the following features: (*a*) decrease in staplelength, which, unless it was due to sampling, could be attributed to the internal corrosion of the fibres which helped in their rupture in repeated opening and repressing of the bale; (*b*) increase in the number of yarn breakages in the ring frame; (*c*) a downward trend in yarn strength; and (*d*) increase in fungal damage to fibres. The extensibility of the yarn was found to increase slightly with storage of cotton.

(2) Storage in desiccators at controlled humidities below 90 per cent R.H. did not lead to any deterioration in bundle-strength over a period of two years, but at saturated humidity the deterioration was so rapid that both Broach Palej and Broach Deshi 8 decayed completely in four to five months.

(3) Storage at humidities immediately above 90 per cent R.H. resulted in loss in strength, the loss being more rapid at higher than at lower humidities. Thus, the critical limit lay between 90 and 92 per cent R.H. The rate of decay increased even with a small increase in storage humidity above 90 per cent R.H.

(4) The incidence of infection was significantly lower for Broach Deshi 8 than for Broach Palej, and there was a significant increase in the percentage of infected fibres in samples stored at 75 per cent R.H. and higher humidities.

(5) Broach Deshi 8 was slightly whiter in shade than Broach Palej ; the shade remained unaffected in storage at 60 and 75 per cent R.H. for a period of two years, but at 90 per cent R.H. and higher humidities the shade of both cottons deteriorated gradually.

(6) Strength tests on small samples stored for two years in petri dishes for shade measurements showed that even at 75 per cent R.H. there was a loss in strength especially in the lower half of the sample. The reason for this loss in strength, which was not shown by the samples stored in desiccators, was found in the accumulation of moisture in the samples in the petri dishes.

(7) Storage for 1½ years at different humidities and a constant temperature of 92°F. did not lead to any decrease in strength or increase in incidence of infection, showing the important role of temperature as a controlling factor for fungal growth. The success of a comparatively low temperature in arresting fungal growth was probably due to absence of any water in the desiccators. This result brings out the importance of storing the cotton in a dry godown.

(8) When cotton is wetted with localized watering, as by the sprinkling or spraying of water, it always results in a loss in strength and shade in the damped region. The loss in strength increases rapidly with the humidity of the atmosphere in which the cotton is stored, and it generally goes hand in hand with increase in fungal infection of fibres. The evil effect of adding water to cotton before pressing it on the ground that dry cotton would not press well, are clearly brought out by these results.

(9) Addition of 0·5 to 1 per cent of formalin of correct commerical concentration to water was found to be quite efficacious in checking the deterioration of cotton on storage. We must, however, make it quite clear that we are not at all in favour of watering cotton in any form whatever, but, if it is indispensable, its evil effects can be greatly reduced by the use of the above-mentioned antiseptic.

Acknowledgements

We have pleasure in recording our gratefulness to members of the Appeal Committee of the East India Cotton Association, Bombay, for their valueable reports on the stored samples of B.D. 8 cotton.

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STUDIES ON THE ROOT-ROT DISEASE OF COTTON IN THE PUNJAB

XII. CONTROL BY VARYING SOWING DATE

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(Received for publication on 31 July 1942)

(With three text-figures)

It has been often observed that an organism is particularly active or that the host plant is highly susceptible during a certain period in its life. In such cases it has been shown by shifting the sowing time that plant is able to escape a severe attack of the disease. The growth of the crop is so adjusted that optimum time of the activity of the organism concerned is evaded.

Cotton in the Punjab is usually sown in the month of May, and soon after irrigation is given, the root-rot disease makes its appearance and rapidly approaches its optimum towards the end of June and continues to be vigorous during July. In August the rate of mortality declines and the disease almost ceases by the end of September [Vasudeva, 1935]. The course of the disease shows that the causal fungi *Rhizoctonia solani* Kühn and *Macrophomina phaseoli* (Maubl.) Ashby [*Rhizoctonia bataticola* (Taub.) Butler] are most active and bring about maximum damage during the months of June and July. Having known the time when the disease is at its highest experiments were carried out in order to control the disease by adjustment of the sowing time. Some experiments in this direction have already been reported [Vasudeva, 1937]. The investigation along this line has since been carried to a stage so that fuller statement of the facts as regards their economic application is now considered necessary.

Experimental results

All the experiments were carried out in heavily infected plots on the randomized system in order further to study the effect of sowing date on the incidence of the disease and also to test the economic application of this method of control of the disease. In earlier experiments equal number of plants were kept in each plot irrespective of the sowing time. The mortality counts were taken at weekly intervals throughout the course of the disease. Data regarding the yield of seed cotton were recorded in each case.

The major portion of the experimental work was conducted at Lyallpur and Khanewal under heavy and uniform conditions of infection in order to obtain reliable and comparable data. In addition some experiments were also conducted at Sargodha. Two experiments were carried out, one in 1936 and the other in 1937, with American cotton variety 4 F (*G. hirsutum*). The sowings were done in a heavily infected plot at Khanewal on different dates between 14 April and 26 June, in order to study the effect of sowing date on the incidence of the disease and yield of seed cotton. The results of both the experiments are summarized in Table I

Table I

Effect of sowing date on the incidence of the disease and yield of seed cotton

1936			1937		
Sowing date	Average percent mortality (4 plots)	Average yield per acre (in lb.)	Sowing date	Average percent mortality (8 plots)	Average yield per acre (in lb.)
14 April	24·02	189	18 April	17·36	155
24 April	21·43	302			
7 May	61·91	160	10 May	32·63	140
14 May	34·22	292			
21 May	54·75	298			
26 May	29·46	361	31 May	51·55	126
4 June	18·75	361			
12 June	18·15	359	14 June	10·40	191
18 June	15·77	424			
25 June	4·46	430	26 June	7·08	248

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The results show that the incidence of the disease is considerably lower in the late crop sown after the middle of June and that the yield of seed cotton tends to be higher in the late-sown crop. In April-sown plots also the mortality is lower than in the case of the plots sown in May but the yield is not materially affected in the case of variety 4F. The yield from plots, however, is economically low as these plots have continuously been under cotton for several years and have received no manure in addition to their being extremely sandy. The plants of the late-sown crop were much smaller in size.

In another experiment conducted in 1936 where *desi* cotton variety Mollisoni 15 (*G. arboreum* var. *neglectum* f. *bengalensis*) was sown on different dates in quadruplicates, the mortality in April-sown plots was 10 per cent as against 40 per cent in May-own plots. The average yield of seed cotton in April-sown plots was 1561 lb. per acre, whereas the average yield obtained from May-sown plots was only 657 lb. per acre. In June-sown plots the mortality was 3 per cent and there was a fall in yield as compared to April-sown plots, though it was higher than May-sown plots. Figure 1 shows the effect of sowing date on root-rot mortality and yield of seed cotton.

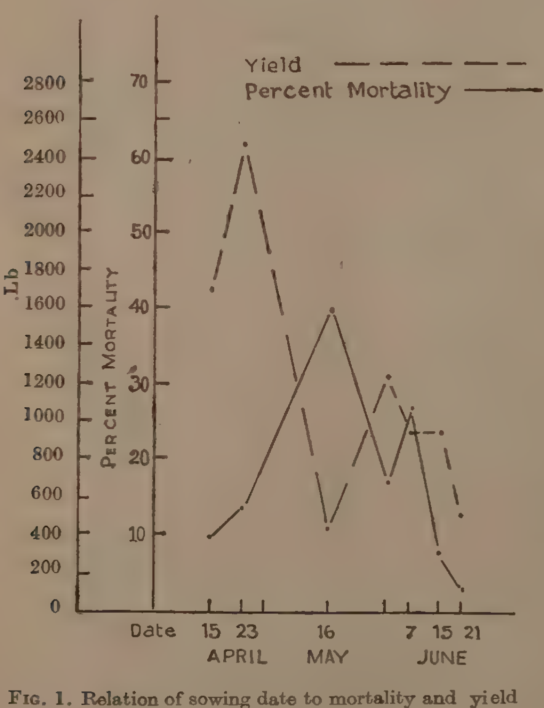

Fig. 1. Relation of sowing date to mortality and yield of seed cotton (per acre)

In 1938 sowing date experiments were conducted again and variety 43 F (*G. hirsutum*) was tested at Khanewal whereas 83 A. F. (*G. hirsutum*) and Mollisoni 39 (*G. arboreum* var. *neglectum* f. *bengalensis*) were tested at Lyallpur. The results of Khanewal and Lyallpur experiments are given in Tables II and III respectively.

Table II

Sowing date as influencing incidence of the disease and yield of seed cotton

Sowing date	Total plants (8 plots)	Total plants killed due to root-rot	Average per cent mortality	Average yield of seed cotton per acre (in lb.)
10-4-38	960	269	28·00	287
11-5-38	960	505	52·60	192
30-5-38	960	699	72·80	281
28-6-38	960	61	6·45	345
6-7-38	960	54	5·60	333

At Khanewal the maximum mortality observed in 30 May sowings was 73 per cent as against 6 per cent in the late-June sown crop, and 28 per cent in the crop sown in the second week of April. The yield of seed cotton tended to be higher both in April and late-June sown crop. The differences were, however, not very marked.

The data of the tests conducted at Lyallpur with the American cotton var. 83 A. F. show that mortality in late-June sown and in crop sown in the first week of April was one and four per cent, respectively, as against 19 per cent in cotton sown on 23 May. The yield of seed cotton was higher in April-sown plots but was lower in cotton sown on 20 June than in May sowings. The plants of late-sown crop were comparatively much smaller in size. It appears that the May sowings yielded a rich crop because the plot was not so severely infected.

Desi cotton variety Mollisoni 39, sown on 23 May, yielded most heavily. The mortality in this crop was 29 per cent as against 43 per cent in the crop sown on 7 May. The yield of seed cotton in both the June sowings and the April sowings was higher than the 7 May sowing, which was most severely attacked.

In 1939 again four experiments were laid out at different stations in order to study the effect of shifting of sowing date on the incidence of the disease and yield of seed cotton. The results of these experiments are summed up in Table IV.

TABLE III

Effect of variation of sowing date on the incidence of the disease and yield of seed cotton

Sowing date	Var. 83 A. F.				Var. Mollisoni 39			
	Total plants (4 plots)	Total killed due to root-rot	Average per cent mortality	Average seed cotton yield per acre (in lb.)	Total plants (4 plots)	Total killed due to root-rot	Average per cent mortality	Average seed cotton yield per acre (in lb.)
5-4-38 . . .	554	22	3·98	1204	544	46	8·39	1489
7-5-38 . . .	559	50	8·94	1100	440	194	42·68	621
23-5-38 . . .	475	100	18·92	1092	560	163	29·10	1511
2-6-38 . . .	551	72	13·06	1146	560	132	23·57	1115
20-6-38 . . .	500	6	1·20	771	548	0	0	784

TABLE IV

Effect of shifting of sowing date on the incidence of the disease and yield of seed cotton

Experiment	Station	Replications	Variety	Sowing date	Average per cent mortality	Average yield per acre (in lb.)
I	Lyallpur .	8	39-Mollisoni . . .	3-4-39	1·4	1453
				7-5-39	37·6	856
				16-5-39	34·0	1021
II	Sargodha .	4	39-Mollisoni . . .	4-4-39	6·8	1660
				12-5-39	23·6	1329
				20-5-39	31·1	1288
				9-6-39	28·9	1385
				20-6-39	7·3	1576
III	Lyallpur .	8	L S S . . .	2-4-39	0·6	500
				8-5-39	32·5	407
				16-5-39	46·5	299
IV	Khanewal .	5	K T 25 . . .	2-4-39	5·9	175
				14-5-39	27·4	190
				23-5-39	31·9	161
				20-6-39	1·7	446
				4-7-39	2·8	524

The data given above clearly show that the disease is markedly reduced in cotton sown after the middle of June and also in the crop sown in the first week of April. The experiment conducted at Khanewal showed a mortality of 2·8 per cent in late-sown crop whereas it was 31·9 per cent in sowing carried out on 23 May. The yield was accordingly higher in the late-sown crop, i.e. 524 lb. as against 160 lb. The mortality in the early-April sown crop was 5·9 per cent whereas yield in this crop was only 175 lb. pèr acre due to bad opening of bolls in this sowing.

At Lyallpur in *desi* cotton (Mollisoni 39) the mortality in April sowing was 1·4 per cent as against 37·6 per cent in May sowing and there was increase of 597 lb. in yield per acre.

In American cotton (L S S) the mortality in early-April sown was 0·6 per cent as compared to 46·5 per cent in mid-May sowing and the corresponding yield had gone up from 299 lb. in the May sowing to 500 lb. The yield in early-sown crop was only 500 lb. because of bad opening of bolls. The growth of the plants and flowering was vigorous. Normally such a crop would be expected to yield approximately 986 lb. to 1232 lb. per acre.

In the case of the experiment conducted at Sargodha the mortality in early-April sown and late-June sown crops was 6·8 and 7·3 per cent, respectively, as against 31·1 per cent in 20 May sowing. The yield of seed cotton had correspondingly gone up by 372 lb. and 288 lb. both in early and late sowings.

By shifting the sowing time from May to about the end of June it was possible to reduce markedly the incidence of the disease, but the yield of seed cotton was sometimes adversely affected. Throughout the experimental work so far described, the number of plants in all the sowings carried out on different dates was kept uniform. The plants of the late-sown crop were much smaller in size and occupied a smaller area in the field. The yields of late-sown crops were further improved by close planting.

Experiments were conducted in heavily infected fields in 1940-41 and close planting was adopted in the late-sowings. In April and May sowings the numbers of plants, to begin with, were the same, but in the case of sowings in the first half and second half of June the number of plants was approximately 12 to 15 and 30 to 32 per cent, respectively, in excess of the May and April sowings. Experiments were laid out at Lyallpur and Khanewal. The results of the experiments are given in Tables V and VI. Figs. 2 and 3 show the effect of sowing date on the incidence of the disease and yield of seed cotton.

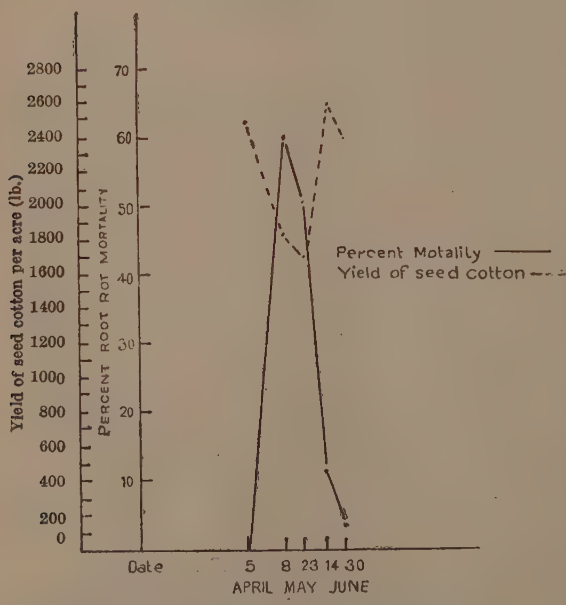

FIG. 2. Effect of sowing date on the incidence of the disease (var. 39 Mollisoni) Lyallpur 1940-41

The results recorded in Tables V and VI bring out the following points of interest :

1. The incidence of root-rot disease of cotton is highest in May-sown crop and appreciably low in the cotton sown in the first week of April and in the end of June.

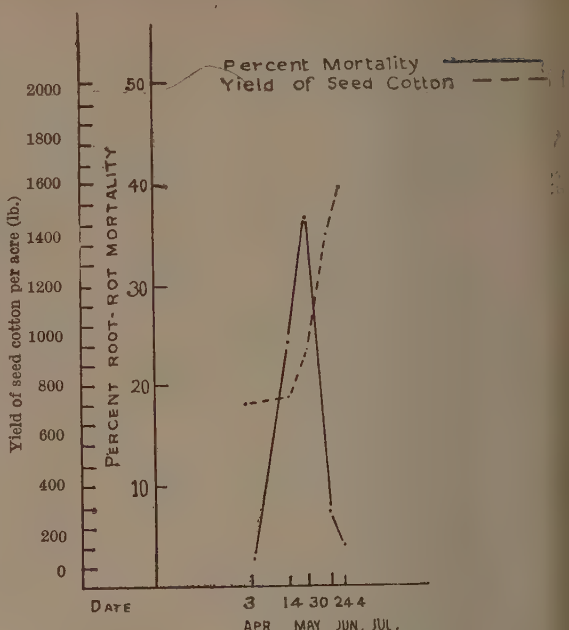

FIG. 3. Effect of sowing date on the incidence of the disease (var. KT 25) Khanewal 1940-41

2. Both *desi* and American varieties when sown late, i.e. about the end of June and planted closely gave significantly higher yields than May-sown crop.

3. American cotton when sown early in April gave low yield. The bolls in these sowings opened badly. *Desi* cotton when sown in the first week of April gave significantly higher yield than May-sown crop.

It has been observed in the past seven years that sowings done on different dates in the month of May show much variation regarding mortality due to root-rot, but it has been established that the maximum damage is caused in the sowings done during the month of May. It is hard to forecast as to which sowing carried out on different dates in May would develop the disease in the most severe form. It has been possible to control root-rot by varying the date of sowing cotton from the month of May to the end of June, i.e. by escaping the period of the maximum virulence of the causal fungi. It has also been shown that the yield from late-sown crop can be further improved by close planting. *Desi* cotton when sown very early, i.e. in the first week of April also escapes a severe attack of the disease, and gives higher yield, but the yield of American cotton when sown so early may be adversely affected in certain seasons due to bad opening of the bolls, though the root-rot mortality is greatly reduced.

TABLE V

Effect of sowing date on the incidence of the disease and yield of seed cotton at Lyallpur

Experiment	Variety	Replications	Sowing date	Total plants	Total killed due to root-rot	Average per cent mortality	Average yield per acre (in lb.)
I	Mollisoni 39 (*G. arboreum* var. *neglectum* f. *bengalensis*)	6	5-4-40	1218	3	0·24	2052
			8-5-40	1218	725	60·91	1502
			23-5-40	1218	459	51·03	1406
			14-6-40	1364	140	11·28	2154
			30-6-40	1581	48	3·24	1984
	S. E. = 238·1797 lb. per acre; 5 per cent critical difference = 496·3828 lb. per acre; 1 per cent critical difference = 685·1406 lb. per acre						
II	L S S (*G. hirsutum*)	4	4-4-40	1800	1	0·05	192
			16-5-40	1794	813	46·66	53
			30-6-40	2365	18	0·76	652
	S. E. = 114·9843 lb. per acre; 5 per cent critical difference = 238·6914 lb. per acre; 1 per cent critical difference = 324·2851 lb. per acre						

TABLE VI

Effect of sowing date on the incidence of the disease and yield of seed cotton at Khanewal—var. KT 25 (G. hirsutum)

Number of replications	Sowing date	Total plants	Total killed due to root-rot	Average per cent mortality	Average yield per acre (in lb.)
5	3-4-40	1190	37	3·18	747
	14-5-40	1180	272	24·08	773
	30-5-40	1190	412	36·22	949
	24-6-40	1365	92	7·01	1432
	4-7-40	1554	52	4·03	1634

S. E. = 84·3086 lb. per acre
5 per cent critical difference = 178·6367 lb. per acre
1 per cent critical difference = 246·3984 lb. per acre

It is worth mentioning that the finding arrived at in the course of the investigation of cotton root-rot disease with regard to the effect of late sowing has found an application for the solution of the serious problem of failure of American cottons now generally known as *tirak* (bad opening of bolls) in the Punjab. The happy agreement over the use of valuable result for overcoming root-rot disease and *tirak* is of very great value in the general success of cultivation of American cotton in the Punjab.

SUMMARY

Experiments on sowing date show that the late-sowings towards the end of June and early sowings in the first week of April escape a severe attack of the disease. May sowings are most severely attacked. Five years data are presented in this connection.

From infected fields a remunerative yield of seed cotton is obtained by sowing the crop about the end of June and by close plantings. Also, a reasonable outturn is obtained from infected fields by sowing *desi* cotton (*G. arboreum* var. *neglectum* f. *bengalensis*) very early, i.e. in the first week of April.

ACKNOWLEDGEMENTS

I wish to place on record here my gratitude to Mr H. R. Stewart, C.I.E., I.A.S., Director of Agriculture, Punjab, and to Rai Bahadur Professor Jai Chand Luthra, I.A.S., for their keen interest and encouragement throughout the course of this investigation. I am also indebted to Sir William Roberts, Kt., C.I.E., and Mr R. P. Jones, for providing facilities for experimental work at the B. C. G. A. Farm at Khanewal. Assistance given by Mr Mulk Raj Sikka, Agricultural Assistant, in the conduct of field trials is gratefully acknowledged. The funds for the investigation were kindly provided by the Indian Central Cotton Committee.

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LONG SMUT OF *SORGHUM PURPUREO-SERICEUM*

By B. N. Uppal, Plant Pathologist to the Government of Bombay and M. K. Patel, Assistant Professor of Mycology, College of Agriculture, Poona

(Received for publication on 17 August 1942)

(With Plate XXII)

Since the creation of the genus *Tolyposporium* by Woronin in 1882, three species of it have been recorded on *Heteropogon* and *Sorghum*. These are *Tolyposporium volkensii* Henn. on *Sorghum cultorum*, *T. philippinense* H. & P. Sydow on *Heteropogon contortus* Roem. & Schult. (*Andropogon contortus* Linn.) occurring in the Philippines, and *T. ehrenbergii* (Kühn) Pat. collected on *Sorghum vulgare* Pers. in Africa, India and Mesopotamia. Of these species *T. volkensii* has been shown by Mason [1926] to be identical with *Cerebella volkensii* (P. Henn.) Mundkur (*C. sorghi-vulgaris* Subram.), and *T. philippinense* is considered by Zundel [1930] to be an *Epicoccum*-like saprophyte, thus leaving only one valid species, viz. *T. ehrenbergii* affecting cultivated sorghum. Zundel [1930], however, considers the latter species to belong to *Sorosporium* and has proposed a new combination *S. filiferum* (W. Busse) Zundel for the fungus occurring in India, Africa and Mesopotamia, retaining the name *S. ehrenbergii* Kühn for the smut found in Turkestan and Egypt.

In a sample of the seed of the wild grass, *Sorghum purpureo-sericeum* Aschers. & Schweinf., received in 1938 from Khandesh, long spore-sacs, each confined to a spikelet of the host, were found, and on examination resembled the sori of *Tolyposporium* on *Sorghum vulgare*. The new smut, however, could easily be distinguished from *T. ehrenbergii* by the large size of its spore-balls. Yet there was much resemblance between the two smuts on the basis of their spore measurements. Accordingly, a comparative study of these smuts was made, and the evidence for considering the smut on *Sorghum purpureo-sericeum* a separate entity is presented in the following pages.

Structural distinctions

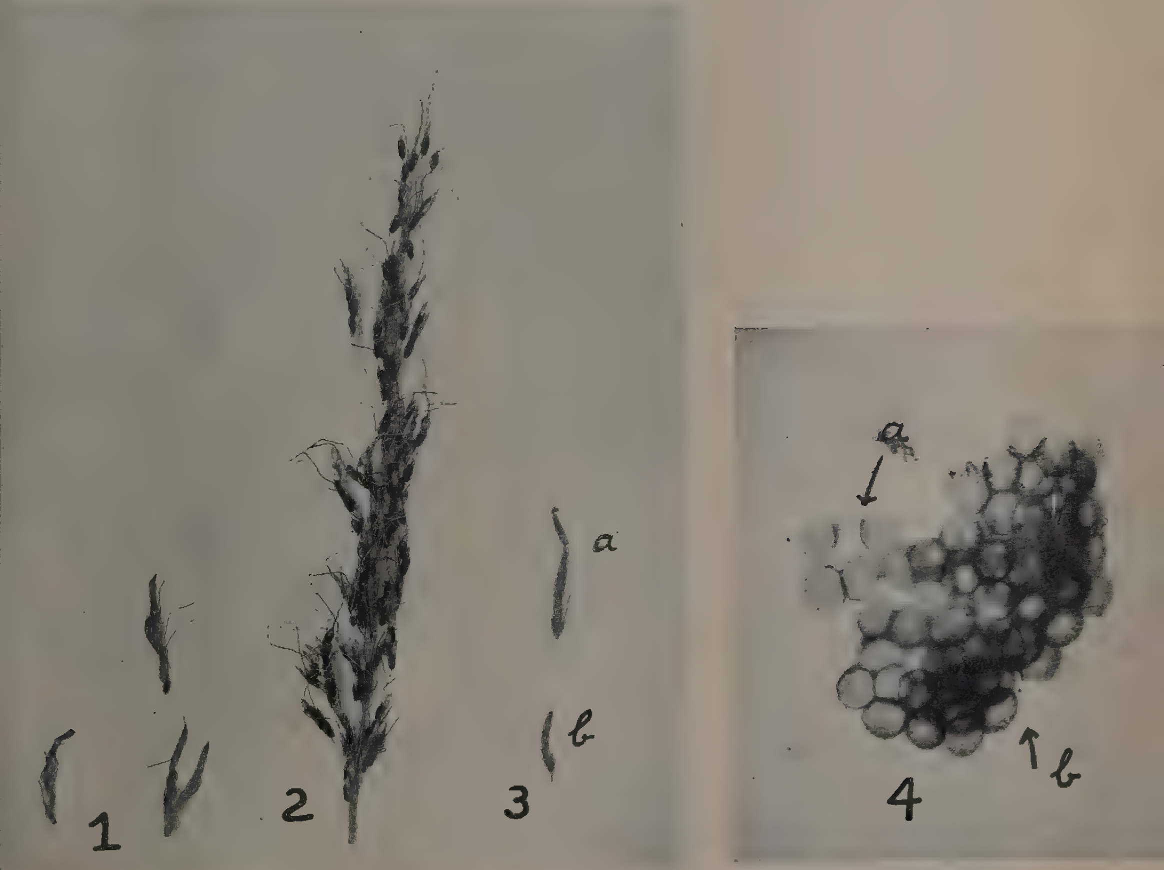
The sori of the smut on *Sorghum purpureo-sericeum* develop in the ovaries, each sorus being confined to a spikelet of the host (Plate XXII, figs. 1 & 3). These are cylindrical elongate bodies, often curved, and measure 1 to 4 cm. in length and 2 to 3 mm. in width. In colour the spore-sacs are usually maize yellow (Ridgway). Each sorus is covered by a thick membrane, which usually ruptures at the sides and sometimes at the tip (Plate XXII, figs. 1 & 3), exposing a granular, dark spore-mass and a number of dark brown threads (up to 10) in place of a central columella.

In *Tolyposporium ehrenbergii* the sori are similar to those of the fungus on *S. purpureo-sericeum*, except that these show slight variations in colour and size. These are baryta yellow (Ridgway), and are 1 to 3 cm. long and 3 to 5 mm. broad, as determined by examination of fresh material of long smut of cultivated sorghum kindly supplied by Mr D. H. Vasishtha, King George V Institute of Agriculture, Sakrand, Sind.

The spore-balls, however, present features sharply distinguishing the smut on *S. purpureo-sericeum*. These balls are formed by the aggregation of spores into persistent masses, which serve to distinguish the genus *Tolyposporium*. In shape and colour there is relatively little difference between the spore-balls of the new smut and those of *T. ehrenbergii* : they are irregular, subglobose to oblong, opaque, dark brown, and are composed of many spores, usually 50 or more in the new smut, but less than 50 in *T. ehrenbergii*. In size, on the other hand, the spore-balls of the two smuts show much difference, and this structural feature differentiates the fungus on *S. purpureo-sericeum* from *T. ehrenbergii* on cultivated *sorghum*. The diameter of the spore-balls of the former fungus is 45 to 239·9 μ (mean 106·7 μ), whereas that of the spore-balls of *T. ehrenbergii* varies from 30 to 119·9 μ (mean 67·5 μ), as shown in Table I.

The spores of the two fungi are similar, being angled and globose (Plate XXII, fig. 4), but show slight variations in colour and size. Those of *T. ehrenbergii* are Mummy brown, whilst spores of *Tolyposporium* on *S. purpureo-sericeum* are Saccardo's umber (Ridgway). The diameter of the spores of the species on sorghum is 9·6 to 15·2 μ (mean 11·9 μ) as opposed to 9·6 to 14·4 μ (mean 11·4 μ) for those of the fungus on *S. purpureo-sericeum* (Table II). The epispore of the outer spores in a spore-ball is covered with dark brown warts on the free side (Plate XXII, fig. 4).

When all the foregoing points are considered, the spore-balls of *Tolyposporium* on *Sorghum purpureo-sericeum*, in their larger size and the greater numbers of spores composing each spore-ball, seem to furnish an adequate basis for its establishment as a variety of *Tolyposporium ehrenbergii*.



1. Affected spikelets showing long sori of *Tolyposporium ehrenbergii* var. *grandiglobum* rupturing at the sides and at the tip. 2. Normal panicle of *Sorghum purpureo-sericeum*. 3. Sorus (a) about 4 cm. long, sorus (b) unruptured. 4. Part of a spore-ball showing (a) angled spores, and (b) warty epispore of outer spores.

TABLE I

Comparison of diameters of spore-balls of Tolyposporium ehrenbergii *and* Tolyposporium *on* Sorghum purpureo-sericeum

Classes in μ	Number of spore-balls in 400	
	Tolyposporium ehrenbergii	*Tolyposporium* on *S. purpureo-sericeum*
30 to 44·9 . .	38	0
45 to 59·9 . .	110	7
60 to 74·9 . .	125	36
75 to 89·9 . .	79	89
90 to 104·9 . .	36	84
105 to 119·9 . .	12	75
120 to 134·9 . .	0	46
135 to 149·9 . .	0	25
150 to 164·9 . .	0	19
165 to 179·9 . .	0	10
180 to 194·9 . .	0	6
195 to 209·9 . .	0	1
210 to 224·9 . .	0	1
225 to 239·9 . .	0	1
Mean	67·5	106·7

TABLE II

Comparison of diameters of spores of Tolyposporium ehrenbergii *and* Tolyposporium *on* Sorghum purpureo-sericeum

Classes in μ	Number of spores in 400	
	Tolyposporium ehrenbergii	*Tolyposporium* on *S. purpureo-sericeum*
9·0 to 9·9 . .	30	35
10·0 to 10·9 . .	46	90
11·0 to 11·9 . .	107	119
12·0 to 12·9 . .	163	134
13·0 to 13·9 . .	33	20
14·0 to 14·9 . .	20	2
15·0 to 15·9 . .	1	0
Mean . . .	11·9	11·4

DIAGNOSIS

The name proposed for the new variety on *Sorghum purpureo-sericeum* is intended to be descriptive of the large size of its spore-balls, thus emphasizing the diagnostic character of the fungus.

Tolyposporium ehrenbergii (Kühn) Pat. var. *grandiglobum* Uppal & Patel, var. nov.

Sori ovaria destruentes, singuli uno hospitis spiculo confines (adhaerentes), cylindrici elongati, 1 ad 4 cm. longi, et 2 ad 3 mm. lati, usualiter curvi, coloris Zhea-mays (Ridgway), denso cooperti membrano, quod ex lateribus et quandoque in extremitate distrahitur, detegens granularem massam nigram sporicam et multa (usque ad decem) nigro-colorata filamenta. Sporo-globuli irregulares, subglobosi usque ad oblongatos, opaci, nigrocolorata, permanentes, compositi usualiter 50 plusve spororum ; diametrus 45 ad 239·9 μ cum medio 106·7 μ ; spori angulati, globosi, Saccardi umber (Ridgway) ; diametrus 9·6 ad 14·4 μ cum medio 11·4 μ ; episporicum coopertum pustulis nigrocoloratis in superficie externa, non asperum sporis intra sporo-globulum.

In Sorghum purpureo-sericeum Aschers. & Schweint. ; Khandesh, Bombaii, Indiae or. December, 1938.

Sori destroying the ovaries, each confined to one spikelet of the host, cylindrical elongate, 1 to 4 cm. long and 2 to 3 mm. broad, usually curved, maize yellow (Ridgway), covered by a thick membrane which ruptures at the sides and sometimes at the tip, exposing a granular, dark spore-mass and a number (up to ten) of dark brown filaments. Spore-balls irregular, subglobose to oblong, opaque, dark brown, persistent, composed of usually 50 or more spores ; diameter 45 to 239·9 μ with a mean of 106.7 μ. Spores angled, globose, Saccardo's umber (Ridgway) ; diameter 9·6 to 14·4 μ with a mean of 11·4 μ ; epispore covered with dark brown warts on the free surface, smooth for spores inside the spore-ball.

On *Sorghum purpureo-sericeum* Aschers. & Schweinf. in Khandesh, Bombay, India, December, 1938.

Type specimens deposited in Herb. College of Agriculture, Poona, and Herb. Mycol. Inst., Kew, England.

SUMMARY

The fungus causing long smut of *Sorghum purpureo-sericeum* is described as a new variety of *Tolyposporium ehrenbergii*, from which it differs by the large size of its spore-balls and the greater numbers of spores in each ball. The name proposed for long smut is *Tolyposporium ehrenbergii* var. *grandiglobum*. The fungus completely destroys the ovaries, producing long sori ; hence the name. The smut is common on *S. purpureo-sericeum* which grows as a wild grass in Khandesh, Bombay Province.

The writers are grateful to Rev. A. R. Cooper, Headmaster, Bishop's High School, Poona, for rendering the diagnosis of the fungus into Latin.

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PARASITIC FUNGI OF THE NORTH-WEST FRONTIER PROVINCE

By SAIED AHMAD MALIK, Mycologist, Department of Agriculture, North-West Frontier Province and M. AZMATULLAH KHAN, Imperial Agricultural Research Institute, New Delhi

(Received for publication on 13 August 1942)

THE major portion of the specimens, on which this report on the parasitic fungi of the North-West Frontier Province is based, were collected by the senior author during the course of the last five years, principally in the Peshawar and the Mardan districts. Dr B. B. Mundkur of the Imperial Agricultural Research Institute, New Delhi, who visited the Agricultural Station, Tarnab (Peshawar), in March 1940, suggested that the specimens should be accurately identified and a report on them published as our knowledge of the fungi of the Frontier Province is very meagre.

An opportunity to do so came to the senior author in February 1941 when he spent two weeks in the Section of Mycology and Plant Pathology of the Imperial Agricultural Research Institute, New Delhi. He was able to obtain there the cooperation of the junior author and they have jointly studied the material and compared it with correctly identified specimens in the *Herbarium Cryptogamae Indiae Orientalis*.

A few fungi collected at Peshawar by late Dr F. J. F. Shaw, former Imperial Mycologist, were kindly made available to the authors and these have been included in this report. Some diseased plants collected by Mr Hafiz Khan, Assistant Botanist, Forest Research Institute and College, Dehra Dun, in the Hazara District and identified by him have also been included in this report and we desire to express our gratitude to him for granting us permission to do so.

More intensive collections in the fertile valleys of the Frontier Province are sure to increase our knowledge of the fungous flora of India and the senior author hopes to carry out this task as time and opportunities permit.

The authors feel indebted to Dr G. Watts Padwick, Imperial Mycologist, for the interest he has taken and help he has provided in the compilation of this report. They are particularly grateful to Dr B. B. Mundkur for his suggesting this work and giving un-reserved help in compiling it. They are also thankful to Khan Mohd. Aslam Khan, Director of Agriculture, for his very kindly providing facilities for the compilation of this paper.

PHYCOMYCETES

Chytridiales

Physoderma Maydis Miyabe (=*P. Zeae-Maydis* Shaw)
  In leaves and culms of *Zea Mays* L. Peshawar Valley

Oomycetes

Bremia Lactucae Regel
  On shoots of *Sonchus* sp. Peshawar Valley

Cystopus Bliti (Biv.) de By.
  On leaves of *Amaranthus Blitum* L. Hazara District, N.-W. F. P. Leg. R. R. Stewart

Peronospora Sisymbrii-officinalis Gäumann
  On leaves of *Sisymbrium Irio* L. Peshawar Valley
  [Included under *Peronospora parasitica* (Pers.) de By. by Butler and Bisby (1931)]

Plasmopara pusila (de By.) Schroet.
  On leaves of *Geranium Wallichianum* Sw. Hazara District, N.-W. F. P.

Pythium aphanidermatum (Edson) Fitzpatrick
  In damped off seedlings of *Capsicum annuum* L. Tarnab, Peshawar
  In rotted cucumbers. Peshawar

ASCOMYCETES

Hemiascomycetes

Taphrina deformans (Berk.) Tul. [=*Exoascus deformans* (Berk.) Fuckel]
  On leaves and twigs of *Prunus persica* Stokes, Peshawar and Kurrum Valley

Discomycetes

Rhytisma acerinum (Pers.) Fr.
  On leaves of *Acer pictum* Thunb. Hazara District, N.-W. F. P.

Pyrenomycetes

Cymadothea Trifolii (Pers.) Wolf (=*Dothidella Trifolii* Bayliss, Elliot & Stansfield) (=*Phyllachora Trifolii* Fckl) (=*Polythrincium Trifolii* Schm. and Kze.).
  On leaves of *Trifolium resupinatum* L. Peshawar Valley

Erysiphe graminis DC.
  On leaves and culms of *Hordeum vulgare* L. and *Triticum vulgare* Host. Throughout N.-W. F. P.

Erysiphe Polygoni DC.
  On leaves of *Chenopodium Botrys* L. and *Sambucus Ebulus* L. Hazara District, N.-W. F. P.
  On shoots of *Pisum sativum* L. Peshawar Valley

Phyllactinia corylea (Pers.) Karst.
On leaves of *Desmodium* sp. Hazara District, N.-W. F. P.

Sphaerotheca humuli (DC.) Burr. var. *fuliginea* (Schlecht.) Salm.
On leaves of *Taraxacum officinale* Wigg. Hazara District, N.-W. F. P.

Uncinula polychaeta (Berk. and Curt.) ex Ellis
On leaves of *Celtis australis* L. Hazara District, N.-W. F. P.

Glomerella cingulata (Stonem.) Spauld. and v Schrenk
On fruit of *Capsicum annuum* L. Peshawar Valley

Guignardia Bidwelli (Pass.) Viala and Ravaz
On leaves of *Vitis vinifera* L. Hazara District, N.-W. F. P. Leg. R. R. Stewart

Mycosphaerella Fragariae (Tul.) Lindau, [=*Sphaerella Fragariae* (Tul.) Sacc.] (=*Ramularia Tulasnii* Sacc.)
On leaves of *Fragaria vesca* L. Peshawar Valley

Mycosphaerella rabiei Kovachevsky, (=*Phyllosticta rabiei* Pass.) [*Ascochyta rabiei* (Pass.) Labrousse]
On stems, petioles and pods of *Cicer arietinum* L. Throughout N.-W. F. P.

Phyllachora Cynodontis (Sacc.) Niessl
On leaves and shoots of *Cynodon Dactylon* Pers. Peshawar Valley

Phyllachora Desmodii P. Henn.
On leaves of *Desmodium* sp. Hazara District, N.-W. F. P.

Polystigma ochraceum (Wahlenb.) Sacc.
On leaves of *Prunus Padus* L. Hazara District, N.-W. F. P.

Basidiomycetes

Ustilaginales

Graphiola Phoenicis (Moug.) Poiteau
On leaves and shoots of *Phoenix dactylifera* L. and *P. sylvestris* Roxb. Bannu and D. I. Khan

Neovossia indica (Mitra Mundkur, (=*Tilletia indica* Mitra)
In grains of *Triticum vulgare* Host, Peshawar Valley

Sphacelotheca Schweinfurthiana (Thum.) Sacc.
In the ovaries of *Imperata arundinacea* Cyrill. (=*I. cylindrica* Beauv.) Peshawar Valley

Urocystis Colchici (Schlecht.) Rabh.
On leaves of *Colchicum luteum* Baker. Hazara District, N.-W. F. P. Leg. R. R. Stewart

Urocystis Tritici Koern.
On leaves of *Triticum vulgare* Host, Peshawar Valley

Ustilago Cynodontis P. Hennings
In inflorescence of *Cynodon Dactylon* Pers. Throughout N.-W. F. P.

Ustilago Hordei (Pers.) Lagerheim
In the ovaries of *Hordeum vulgare* L. Throughout N.-W. F. P.

Ustilago nuda (Jens.) Rostrup
In the ovaries of *Hordeum vulgare* L. Throughout N.-W. F. P.

Ustilago scitaminea Sydow (=*U. Sacchari* Auct.)
In inflorescence and culms of *Saccharum officinarum* L. Tarnab, Peshawar

Ustilago Tritici (Pers.) Rostrup
In ovaries of *Triticum vulgare* Host. Throughout N.-W. F. P.

Uredinales

Aecidium Berberidis (=*Puccinia graminis* Pers.)
On leaves of *Berberis* sp. Hazara District N.-W. F. P.

Aecidium callianthum Syd.
On leaves of *Desmodium tiliaefolium* G. Don. Hazara District, N.-W. F. P. Leg. R. R, Stewart

Aecidium crypticum Kalchbr & Cooke
On leaves of *Gerbera lanuginosa* Benth. Hazara District, N.-W. F. P.

Chrysomyxa deformans (Diet.) Jaczew.
On leaves of *Picea Morinda* Link (=*Abies Smithiana* Forbes). Kurrum Valley

Cronartium ribicola Fischer
On leaves of *Ribes rubrum* L. Hazara District, N.-W. F. P.

Melampsora ciliata Barclay
On leaves of *Populus ciliata* Wall. Hazara District, N.-W. F. P.

Melampsora Euphorbiae-gerardianae Mueller
On leaves of *Euphorbia* sp. Hazara District. N.-W. F. P.

Melampsora helioscopiae (Pers.) Wint.
On leaves of *Euphorbia Helioscopia* L. Hazara District, N.-W. F. P.
On leaves of *E. pilosa* L. Hazara District, N.-W. F. P.

Melampsora Larici-caprearum Kleb.
On leaves of *Salix tetrasperma* Roxb. Kohat

Monosporidium Andrachnis Barclay.
On leaves of *Andrachne cordifolia* Muell. Hazara District, N.-W. F. P.

Peridermium indicum Colley & Taylor
On needle of *Pinus excelsa* Wall. Hazara District, N.-W. F. P.

Phakopsora Zizyphi-vulgaris Diet.
On leaves of *Zizyphus sativa* Gaertn. Hazara District, N.-W.F.P.
On leaves of *Z. vulgaris* Lamk. Hazara District, N.-W.F.P.

Phragmidium Butleri Syd.
On leaves of *Rosa macrophylla* Lindl. Hazara District, N.-W. F. P.

Phragmidium nepalense Barcl.
On leaves of *Potentilla nepalensis* Hook. Hazara District, N.-W.F.P.

Phragmidium Potentillae (Pers.) Karst.
On leaves of *Potentilla nepalensis* Hook. Hazara District, N.-W.F.P.

Phragmidium Rosae-moschatae Diet.
On leaves of *Rosa centifolia* L. Peshawar proper
On leaves of *Rosa* sp. Peshawar Valley

Puccinia Centaureae Mart.
On leaves of *Centaurea Calcitrapa* L. Hazara District, N.-W.F.P. Leg. R. R. Stewart

Puccinia Circaeae Pers.
On leaves of *Circaea alpina* L. Hazara District, N.-W.F.P.

Puccinia coronata Corda
On leaves of *Rhamnus dahuricus* Pall. (=*R. virgatus* Roxb.) Peshawar Valley

Puccinia glumarum (Schm.) Erikss. & Henn.
On leaves of *Triticum vulgare* Host, and *Hordeum vulgare* L. Throughout N.-W.F.P.

Puccinia graminis Pers.
On leaves and culms of *Triticum vulgare* Host. Throughout N.-W.F.P.
On leaves and stems of *Hordeum vulgare* L. Throughout N.-W.F.P.

Puccinia Menthae Pers.
On leaves of *Mentha longifolia* (L.) Hudson. Peshawar Valley

Puccinia nepalensis Barcl. & Diet.
On leaves of *Rumez* sp. Hazara District, N.-W.F.P.

Puccinia nitida Barcl.
On leaves of *Polygonum amplexicaule* D. Don. Hazara District, N.-W.F.P.
On leaves of *Polygonum* sp. Hazara District, N.-W.F.P.

Puccinia Prostii Moug.
On leaves of *Tulipa stellata* Hook. Hazara District, N.-W.F.P. Leg R. R. Stewart

Puccinia Pruni-spinosae Pers.
On leaves of *Prunus persica* Stokes. Peshawar Valley

Puccinia Ribis DC.
On leaves of *Ribes rubrum* L. Hazara District, N.-W.F.P.

Puccinia Saxifragae-ciliatae Barcl.
On leaves of *Saxifraga iqulala* Wall. Hazara District, N.-W.F.P.

Puccinia Solmsii P. Henn.
On leaves of *Polygonum* sp. Hazara District, N.-W.F.P.

Puccinia Sonchi Rob.
On leaves of *Sonchus arvensis* L. Hazara District, N.-W.F.P.

Puccinia triticina Erikss.
On leaves of *Triticum valgare* Host. Throughout N.-W.F.P.

Puccinia Violae (Schum.) DC.
On leaves of *Viola serpens* Wall. Hazara District, N.-W.F.P.

Pucciniastrum Agrimoniae (Schw.) Tranzsch.
On leaves of *Agrimonia Eupatorium* L. Hazara District, N.-W.F.P.

Uromyces appendiculatus (Pers.) Link
On leaves of *Dolichos Lablab* L. Tarnab, Peshawar

Uromyces Fabae (Pers.) de By.
On leaves of *Lathyrus odoratus* L. and *Vicia Faba* L. Peshawar Valley

Uromyces Polygoni (Pers.) Fuckel
On leaves of *Polygonum aviculare* L. and *P. viviparum* L. Hazara District, N.-W.F.P.

Uromycestrifolii (Hedwig f.) Lev.
On leaves of *Trifolium resupinatum* L. Peshawar Valley

Hymenomycetes

Botryobasidium Solani (Prill. and Delacr.) Donk (Rhizoctonia *Solani* Kuhn)
On roots and stems of *Hibiscus esculentus* L. Peshawar Valley

Polyporus ostreiformis Berk.
On dead wood of *Prunus persica* Stokes. Tarnab, Peshawar

Fungi Imperfecti

Moniliales

Alternaria Brassicae (Berk.) Sacc.
On leaves and pods of *Brassica campestris L.* and *Brassica sp.* N.-W.F.P.
On leaves of *Raphanus sativus* L., N.-W.F.P.

Alternaria Citri Pierce
On fruits of *Citrus sinensis* Osbeck, Peshawar Valley

Alternaria macrospora Zimm.
On leaves of *Gossypium* sp. Tarnab, Peshawar

Altermaria solani (Ell. & Mart.) Jones & Grout.
On leaves of *Solanum tuberosum* L. N.-W.F.P.
On leaves of *Passiflora* sp. Tarnab, Peshawar

Cephalosporium Sacchari Butler
In roots and stems of *Saccharum officinarum* L. Peshawar Valley

Cercospora annulata Cooke
On leaves of *Ficus* sp. Peshawar Valley

Cercospora anthelmintica Atk.
On leaves of *Chenopodium ambrosioides* L. Hazara District, N.-W. F. P. Leg. R. R. Stewart

Cercospora Asparagi Sacc.
On shoots of *Asparagus officinalis* L. Tarnab, Peshawar

Cercospora beticola Sacc.
On leaves of *Beta vulgaris* L. Tarnab, Peshawar
On leaves of *Spinacea oleracea* L. Peshawar Valley

Cercospora Cannabina Wakef.
On leaves of *Cannabis sativa* L. Peshawar Valley

Cercospora Dolichi Ell. & Ev.
On leaves of *Dolichos Lablab* L. Tarnab, Peshawar

Cercospora Gossypina Cooke
On leaves of *Gossypium* sp. Tarnab, Peshawar

Cercospora moricola Cooke
On leaves of *Morus alba* L. D. I. Khan and Peshawar Valley

Cercospora rosicola Thüm.
On leaves of *Rosa centifolia* L. and *R. damascena* Mill. Peshawar Valley

Cercospora subsessilis Syd.
On leaves of *Melia Azedarach* L. Peshawar Valley and Hazara district

Cercospora viticola (Ces.) Sacc. (=*C. Vitis* Sacc.)
On leaves and twigs of *Vitis vinifera* L. N.-W. F. P.

Cladosporium herbarum (Pers.) Link
On culms and ears of *Triticum vulgare* Host Peshawar Valley

Clasterosporium carpophilum (Lev.) Aderh.
On leaves of *Prunus communis* Fritsch, (=*P. Amygdalus* Stokes). Tarnab.

Coniothecium chomatosporum Corda
On twigs and fruits of *Pyrus Malus* L. Hazara District, N.-W. F. P.

Fusarium orthoceras App. & Wr. var. *Ciceris* Padwick
On roots of *Cicer arietinum* L. Peshawar, Kohat and Bannu

Fusarium udum Butler var. *Crotalariae* (Kulk) Padwick
On roots of *Crotalaria juncea* L. Tarnab, Peshawar

Helminthosporium Avenae Eidam
On leaves of *Avena sativa* L. Peshawar Valley

Helminthosporium sativum Pammel, King & Bakke
On leaves of *Triticum vulgare* Host and *Hordeum vulgare* L. Peshawar Valley

Piricularia Oryzae Cavara
On leaves of *Triticum vulgare* Host. Hazara District, N.-W. F. P. Leg. R. R. Stewart

Pucciniopsis quercina Wakef.
On leaves of *Quercus dealbata* Wall. (= *Q. incana* Roxb.). Hazara district

Polystigmina rubra (Desm.) Sacc.
On leaves of *Prunus cornuta* Hazara district

Stigmina Platani (Fuckel) Sacc.
On leaves of *Platanus orientalis* L. Peshawar Valley and Hazara District

Melanconiales and *Sphaeropsidales*

Ascochyta Pisi Lib.
On shoots of *Cicer arietinum* L. N.-W. F. P.

Colletotrichum Capsici (Syd.) Butler & Bisby (=*Vermicularia Capsici* Syd.)
On leaves, stems and fruits of *Capsicum annuum* L. Peshawar Valley

Colletotrichum falcatum Went
In the roots and stems of *Saccharum officinarum* L. N.-W. F. P.

Colletotrichum gloeosporioides Penz.
On twigs, leaves and fruits of *Citrus sinensis* osbeck. *C. Aurantium* L., *C. limonia* Osbeck and *C. aurantifolia* (Christm.) Swingle, N.-W. F. P.

Colletotrichum graminicolum (Ces.) Wilson
On leaves of *Andropogon sorghum* (=*Sorghum vulgare* Pers.) Peshawar Valley

Phyllosticta pirina Sacc.
On twigs and leaves of *Pyrus communis* L Peshawar Valley

Septoria Aitchisoni Syd.
On leaves of *Jasminum humile* L. Kurrum Valley

Septoria Tritici Desm.
On culms and leaves of *Triticum vulgare* Host, Peshawar Valley

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Acer pictum Thunb .	*Rhytisma acerinum* (Pers.) Fr.
Agrimonia Eupatorium L.	*Pucciniastrum Agrimoniae* (Schw.)Tranzsch.
Amaranthus Blitum L.	*Cystopus Bliti* (Biv.) de By.
Andrachne cordifolia Muell.	*Monosporidium Andrachnis* Barcl.
Andropogon Sorghum Brot. (=*Sorghum vulgare* Pers.).	*Colletotrichum graminicolum* (Ces.) Wilson.

Asparagus officinalis L.	*Cercospora Asparagi* Sacc.
Avena sativa L.	*Helminthosporium Avenae* Eidam.
Berberis sp.	*Aecidium Berberidis* Pers.
Beta vulgaris L.	*Cercospora beticola* Sacc.
Brassica campestris L.	*Alternaria Brassicae* (Berk.) Sacc.
Brassica sp.	Do. Do.
Cannabis sativa L.	*Cercospora cannabina* Wakef.
Capsicum annuum L.	*Colletotrichum Capsici* (Syd.) Butl. & Bisby.
	Glomerella cingulata (Stonem.) Spauld. & v. Schrenk.
	Pythium aphanidermatum (Edson.) Fitz.
Celtis australis L.	*Uncinula polychaeta* (Berk. & Curt.) Ex. Ellis.
Centaurea Calcitrapa L.	*Puccinia Centaureae* Mart.
Chenopodium ambrosioides L.	*Cercospora anthelmintica* Atk.
Chenopodium Botrys L.	*Erysiphe Polygoni* DC.
Cicer arietinum L.	*Ascochyta Pisi* Lib.
	Fusarium orthoceras App. & Wr. var. *Ciceris* Padwick.
	Mycosphaerella rabiei Kovachevsky.
Circaea alpina L.	*Puccinia Circaeae* Pers.
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Citrus Aurantium L.	Do. Do.
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	Colletotrichum gloeosporioides Penz.
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	Ustilago Cynodontis P. Henn.
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Desmodium sp.	*Phyllachora Desmodii* P. Henn.
	Phyllactinia corylea (Pers.) Karst.
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Euphorbia sp.	*Melampsora Euphorbiae-gerardianae* Muller
Ficus sp.	*Cercospora annulata* Cooke
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Gossypium sp.	*Alternaria macrospora* Zimm.
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Hibiscus esculentus L.	*Botryobasidium Solani* (Prill. & Delacr.) Donk.
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	Helminthosporium sativum Pammel, King & Bakke
	Puccinia glumarum (Schm.) Erikss. & Henn.
	Puccinia graminis Pers.
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Lathyrus odoratus L.	*Uromyces Fabae* (Pers.) de By.
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Polygonum aviculare L.	*Uromyces Polygoni* (Pers.) Fuckel
Polygonum viviparum L.	Do. Do.
Polygonum sp.	*Puccinia nitida* Barclay
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Populus ciliata Wall	*Melampsora ciliata* Barclay
Potentilla nepalensis Hooker.	*Phragmidium nepalense* Barcl.
Potentilla nepalensis Hooker.	*Phragmidium Potentillae* (Pers.) Karst.
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Prunus cornuta L.	*Polystigmina rubra* (Desm.) Sacc.
Prunus Padus L.	*Polystigma ochraceum* (Wahlenb.) Sacc.
Prunus persica Stokes	*Polyporus ostreiformis* Berk.
	Puccinia Pruni-spinosae Pers.
	Taphrina deformans (Berk.) Tul.
Pyrus communis L.	*Phyllosticta pirina* Sacc.
Pyrus Malus L.	*Coniothecium chomatosporum* Corda
Quercus dealbata Wall. (=*Q. incana* Roxb.).	*Pucciniopsis quercina* Wakf.
Raphanus sativus L.	*Alternaria Brassicae* (Berk.) Sacc.
Rhamus dahuricus Pall. (=*R. virgatus* Roxb.)	*Puccinia coronata* Corda
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Rosa centifolia L.	*Cercospora rosicola* Thüm.
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Rosa damascena Mill	*Cercospora rosicola* Thüm.
Rosa macrophylla Lindl.	*Phragmidium Butleri* Syd.
Rosa sp.	*Phragmidium Rosae-moschatae* Dietel
Rumex sp.	*Puccinia nepalensis* Barcl. & Diet.
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	Colletotrichum falcatum Went
	Ustilago scitaminea Sydow
Salix tetrasperma Roxb.	*Melampsora Larici-caprearum* Kleb.
Sambucus Ebulus L.	*Erysiphe Polygoni* DC.
Saxifraga ligulata Wall.	*Puccinia Saxifragae-ciliatae* Barclay
Sisymbrium Irio L.	*Peronospora Sisymbrii-officinalis* Gäumann
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Sonchus arvensis L.	*Puccinia Sonchi* Rob.
Sonchus sp.	*Bremia Lactucae* Regel
Spinacea oleracea L.	*Cercospora beticola* Sacc.
Taraxacum officinale Wigg.	*Sphaerotheca humuli* (DC.) Burr. var. *fuliginea* (Schlecht.) Salm.
Trifolium resupinatum L.	*Cymodothea Trifolii* (Pers.) Wolf
	Uromyces Trifolii (Hedwig f.) Lév.
Triticum vulgare Host	*Cladosporium herbarum* (Pers.) Link
	Erysiphe graminis DC.
	Helminthosporium sativum Pammel, King & Bakke
	Pirricularia Oryzae Cavara
	Neovossia indica (Mitra) Mundkur
	Puccinia glumarum (Schm.) Erikss. & Henn.
	Puccinia graminis Pers.
	Puccinia triticina Erikss.
	Septoria Tritici Desm.
	Urocystis Tritici Koern.
	Ustilago Tritici (Pers.) Rostrup
Tulipa stellata Hook	*Puccinia Prostii* Moug.
Vicia Faba L.	*Uromyces Fabae* (Pers.) de By.
Viola serpens Wall.	*Puccinia Violae* (Schm.) DC.
Vitis vinifera L.	*Cercospora viticola* (Ces.) Sacc. (=*C. vitis* Sacc.)
	Guignardia Bidwelli (Pass.) Viala and Ravaz
Zea Mays L.	*Physoderma Maydis* Miyabe
Zizyphus sativa Gaertn.	*Phakopsora Zizphi-vulgaris* Diet.
Zizyphus vulgaris Lamk.	Do. Do.

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THE PINK DISEASE OF APPLE IN KUMAUN

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(Received for publication on 4 January 1943)

The pink disease of apple in Kumaun is caused by *Corticium salmonicolor* Berk. et. Broome, and was recorded for the first time in Chaubattia by Singh [1934].

Muller [1936] reports it on *Pyrus malus* from Brazil. Birmingham [1936] reports it on a 25 years' old Canington apple and two Allsop apple trees at Longhtondale in New South Wales.

This disease has got a wide host range of 141 species of plants belonging to 104 genera and many different families. The disease has been found on Gymnosperms and Dicotyledons but not on Monocotyledons. Rant [1912] recorded it on the epiphytic fern *Drymoglossum heterophyllum* without apparently causing harm.

In some orchards in Kumaun this disease is known to cause considerable damage to apple and pear trees. The incidence of the disease was found most in those areas where the drainage was not good and the trees were overcrowded, thereby increasing humidity and obstructing light. Old trees are found more susceptible to this disease than young ones. It was once recorded by Singh [1936] on apricot from Ghorakhal Orchard (Bhowali).

Pathogenecity experiment

The pathogenecity of the fungus was established by a series of inoculation experiments. The fungus can enter both from uninjured and injured portions of stem. The inoculated portion becomes shrivelled up and turns light brown in colour and soon the bark turns papery and loose. Then, small white pustules appear all over the affected portion and ultimately break through the bark in pink coloured masses of the size of pin heads. This is the nodular stage of the fungus. The leaves turn brown and wilt.

(*a*) *Artificial inoculation*

A record of the progress of infection of artificially inoculated apple plants, inoculated on 19 September 1935, was taken from 13 February 1936 up to 22 February 1937. The measurement of the infected portions was carried out after every 15 days. Another experiment was started on 5 May 1936 and the data on the progress of infection were recorded from the 19 June 1936 up to 31 March 1937. In both the experiments it was found that the rate of the progress of infection was the greatest in the month of August and the beginning of September, that is during the rainy season. Dry weather does not favour increase of infection.

(*b*) *Cross inoculation*

Three replicated cross inoculation experiments of the five different strains of the fungus isolated from apple, pear and apricot were conducted respectively on (1) peach, pear and apricot; (2) apple, peach and apricot; and (3) apple, pear and peach. It was found that the parasitism of none of the strains was restricted to the host from which it was isolated. Rant [1912] also experimentally demonstrated that *Corticium salmonicolor* B. & Br. does not exhibit specialized parasitism. Thus this fungus occurring on one host is not limited in infection power to that host or a few others but can pass from one host to another.

Sources of infection

In Kumaun the *Necator* stage has been found much more frequently than the *Corticium* (basidial) stage, and it is likely that it takes the more active part in the dissemination of the disease. Small incrustations of the sterile nodular stage which remain viable for a year or so may also be one of the sources of infection. The *Necator* spores and small incrustations of the sterile nodular stage of the fungus most probably get spread either by means of wind or rain. *Necator* spores are sometimes seen in vaseline smeared aeroscope slides.

Control measures

The fungus is also capable of entering through the sound bark. The commonest seat of infection is the fork of a branch or stem, this being the dampest part of the bark. The fungus is also sometimes observed to enter through unprotected pruned surfaces of branches. Hence the effective control measures consist in painting the forks of the branches especially thick ones because these are more susceptible than the thin ones with some protective paint before the onset of the monsoon and also by covering the unprotected pruned surfaces of stem with some suitable paint.

Painting the forks

Anstead [1911] reported that painting the forks of young rubber trees with Bordeaux mixture before the coming of the monsoon reduced the

percentage of trees affected from 1·34 to 0·56, 0·07 (three applications of the fungicides were given here); and the infection was reduced in most cases to 0·7 per cent. Painting forks of branches especially thick ones with some protective paint before the onset of the monsoon appeared to be the most suitable means of preventing this disease. With this point in view a replicated control experiment was laid out at the Government Orchard, Chaubattia, on apple, variety, Jonathan; 12 trees of which were selected at random in the orchard. The treatments were (i) untreated and uninoculated (control I); (ii) untreated and inoculated (control II); (iii) painted with red lead and copper carbonate equal amounts in raw linseed oil and inoculated (the paste was prepared by mixing 2 oz. of red lead and 2 oz. of copper carbonate in 100 c.c. of raw linseed oil); (iv) painted with red lead and Bordeaux dust in raw linseed oil and inoculated (the paste was prepared by mixi ng2 oz. of red lead with 2 oz. of Bordeaux dust 4 : 4 : 50 in 100 c.c. of raw linseed oil); (v) painted with Bordeaux dust in raw linseed oil and inoculated (the paste was prepared by mixing 4 oz. of Bordeaux dust 4 : 4 : 50 in 100 c.c. of raw linseed oil and inoculated); and (vi) painted with self-boiled lime-sulphur paste in raw linseed oil and inoculated (the paste was prepared by mixing 2 oz. of quicklime and 2 oz. of sulphur, and allowing it to self boil with water to which 100 c.c. of raw linseed oil was added to form the paste). Six forks of each of the 12 apple trees, (variety Jonathan) were selected at random in the orchard in Blocks A-S and were treated with six above mentioned treatments. Each treatment was replicated six times. After the paint had dried the treated and untreated surfaces were inoculated with the culture of the fungus, covered over with sterilized wet absorbant cotton and then with cellophane bags. Six inoculations were done at intervals of 10 days. The observations were taken after two and a half months after the first inoculation.

Analysis of variance was carried out and it was found that the difference between the treatments were very highly significant. As regards the individual treatment difference, it appears that the mean value for treatment (iii) is not significantly different from those for treatments (iv), (i) and (v), but is significantly lower than those for treatments (vi) and (ii). Among the treatments (iv), (v) and (vi) there are no significant differences, but the mean values for them are all significantly lower than that for treatment (ii).

It is concluded that the treatment (iii), viz. a paste of red lead and copper carbonate equal amounts in raw linseed oil is the most effective paste in preventing the disease although there is no significant difference between treatments (iii), (iv) and (v). The results can be summarized thus—iii = iv = v > ii > vi.

Painting the pruned surfaces

It is sometimes observed that the fungus *Corticium salmonicolor* also gains entrance through unprotected pruned surfaces of stem. Birmingham [1936] recommended the use of white lead or tar for cut surfaces of apple trees and a dormant spraying of Bordeaux mixture 6 : 4 : 40 or lime-sulphur (1 in 14). In order to find out a suitable paste which could prevent the entry of the fungus through injured surfaces a replicated control experiment was started in June 1941 by using lanoline for making the paste. Singh [1938-39]* and [1942] found that red lead and copper carbonate equal amounts in lanoline (4 : 4 : 5) is very effective in preventing the entry of the fungi *Coniothecium chomatosporum* Corda. (the causal organism of the stem-black disease of apple); and *Botryosphaeria ribis* G. and D., the causal organism of the stem-brown disease through pruned surfaces of stem.

Both mature and immature twigs were experimented upon. For each experiment 1- old apple trees of variety Jonathan, spread all over the orchard were selected at random. Each treatment was replicated six times in each of the 12 trees. The treatments consisted of (i) untreated and uninoculated (control I); (ii) treated with lanoline and uninoculated; (iii) treated with lanoline and inoculated; (iv) untreated and inoculated (control II); (v) treated with lanoline mixed with an equal amount of red lead and copper carbonate and inoculated; and (vi) treated with red lead and copper carbonate equal amounts mixed with raw linseed oil and inoculated. The weight of the lanoline used was the same as that of raw linseed oil.

After the paints had dried, the treated and untreated surfaces were inoculated with the fungus culture covered over with sterilized wet absorbant cotton and then with cellophane bags. The six inoculations were done at intervals of 10 days. The twigs were examined after three months.

Analyses of variance was carried out and it was found that in both the cases of immature and mature twigs treatment differences were highly significant. Further, it was found that treatment (v) was most effective in controlling the pink disease, the mean value corresponding to it being significantly lower than that for all the other treatments. The mean value for treatment (vi) was significantly lower than that for treatments (i), (ii), (iii) and (iv), so that this treatment came out to be the next best in controlling the disease. The mean value of treatment (ii) was not significantly different from treatment (i) but

* The results were not published in any journal

was significantly lower than that for treatments (iv) and (iii), there being no significant difference between the latter.

Thus it is concluded that the paste of red lead and copper carbonate equal amounts in lanoline (4 : 4 : 5) is the most effective paste in preventing this disease. The above paste can effectively control three important stem diseases of apple, viz. stem-black caused by *Coniothecium chomatosporum* (1938-39) ; stem-brown caused by *Botryosphaeria ribis* (1942) ; and pink disease caused by *Corticium salmonicolor*.

Removal of affected branches

The already affected branches must be cut off at least two feet below the pink incrustation and burnt or buried after dipping in 50 per cent copper sulphate solution. The cut end should be smoothed over and painted with the paste of red lead and copper carbonate equal amounts in lanoline (4 : 4 : 5). Brooks [1915] recommended that in rubber plantations where the pink disease appears for the first time diseased branches should be cut off at least two feet below the lowest point where there are obvious signs of the fungus and it is preferable to cut them off flush with the main stem of larger branches. In estates where larger numbers of trees are affected the manager will probably hesitate before cutting the diseased branches in this drastic manner. As an alternative, branches and main stem which appear to have a chance of recovery should be covered over with a paste of red lead and copper carbonate equal amounts in raw linseed oil (4 : 4 : 5) for two feet above and below the region over which the fungus is evident. If the disease is dealt with in this way in the early stages many branches and sometimes entire trees may be saved.

Destruction of other affected hosts

Any trees besides apple which are found affected by pink disease in the neighbourhood of the orchard should be destroyed at once as the fungus passes readily from one host to another.

Summary

Pink disease is caused by *Corticium salmonicolor* Berk. et. Broome which have been recorded for the first time at Chaubattia, India, on apple, pear and apricot.

Pathogenecity of the fungus was established by series of inoculation experiments. Progress of infection was the greatest from August to the middle of September. The fungus does not exhibit specialized parasitism, as it readily passes from one host to another.

Necator spores and less frequently dry incrustations of the sterile nodular stage carried either by wind or rain water are the chief sources of infection.

The disease can be successfully controlled by the following methods :

(*a*) By painting the forks of branches before the onset of the monsoon with a paste of red lead and copper carbonate equal amounts in raw linseed oil (4 : 4 : 5).

(*b*) By painting the pruned surface with a paste of red lead and copper carbonate equal amounts in lanoline (4 : 4 : 5).

(*c*) By cutting away the already affected branches at least two feet below the last point of infection and burning them or burying the affected cut branches after dipping them in a solution of 50 per cent copper sulphate.

(*d*) By destruction of other hosts affected with the pink disease.

Acknowledgements

My sincere thanks are due to Mr P. K. Dey, Plant Pathologist to Government, United Provinces, for taking keen interest in the work and Dr E. J. Butler, the former Director of the Imperial Mycological Institute, Kew, Surrey, for kindly confirming the identification of the fungus. The financial help of the Imperial Council of Agricultural Research is acknowledged. Gratitude is expressed to Mr Kunwar Kishen, Statistician to Government, United Provinces, for analyzing the data.

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DRAIN GAUGE (LYSIMETER) STUDIES AT PUSA DURING THIRTY YEARS*

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(Received for publication on 11 February 1943)

(With one text-figure)

The rain that falls in an agricultural area is disposed off in many ways. Depending on the topography, the nature of the soil of the area, and on the intensity and frequency of the rainfall, a greater or a smaller part of the rain water is lost as surface flow. A part is lost by direct evaporation and a part percolates through the soil. Agriculturists are concerned firstly with that portion of the rainfall that enters the soil and is directly available for crop growth and secondly with that which drains below and joins the subsoil water which is used as well irrigation. A knowledge of the amount of water that is held by the soil and of the amount and the composition of the water that percolates is of interest from the point of view of crop growth.

J. W. Leather instituted these studies as early as 1903 by erecting drain gauges or lysimeters, first at Cawnpore and later at Pusa. The drain gauges which were constructed after the model of those at Rothamsted were described by Arnott and Leather [1907]. At Cawnpore the drain gauges were constructed in 1903. They were four in number, each having a superficial area of 0.001 acre. Two of the gauges contained soil to a depth of 6 ft. and the other two had soil 3 ft. deep. The drain-gauges at Pusa were constructed in 1906 in an exactly similar manner to those at Cawnpore. The difference lay only in the nature of the local soils—the Pusa soil being of a highly calcareous nature. In every case care was taken in inclosing the undisturbed block of soil into its original state.

There were four gauges: two of 6 ft. depth and two of 3 ft. depth. One deep and one shallow gauge were cropped with maize and the other set of one deep and one shallow gauge was kept fallow.

The records maintained were: (*a*) the amount of rain water that drained away through the cropped and uncropped drain gauges; (*b*) the evaporation which took place under bare fallow conditions, calculated on the difference between rainfall and percolation; and (*c*) the amounts of ammoniacal and nitrate nitrogen which were washed out of the soil under cropped and uncropped conditions.

The data collected up to the year 1911 were discussed by Leather [1911]. The conclusions reached were: (*a*) Rainfall percolating during wet weather passes uniformly through the soil; (*b*) the amount of percolation varied with rainfall and transpiration by plants was nearly independent of the season; (*c*) the effect of crop was to reduce evaporation from soil surface to two-thirds or one-half of what it would be from a fallow land; and (*d*) the amount of ammonia in the drainage from cropped or fallow land was small while the amount of nitrate was much larger than at Rothamsted.

The present paper deals with the observations and records which were continued from 1911 till 1934 with some modifications in the cropping programme of the gauges. The following is the description of the drain gauges and cropping programme:

Drain gauge I—6 ft. deep; was formerly kept fallow; in the modified scheme under wheat—a *rabi* or cold weather crop.

Drain gauge II—6 ft. deep; was formerly cropped with maize; in the modified scheme sann hemp (*Crotolaria juncea*) was grown in summer; the crop was cut-off after flowering and removed (not incorporated in the soil); wheat was grown in winter.

Drain gauge III—3 ft. deep; formerly kept fallow; in the modified scheme also, was kept bare fallow throughout.

Drain gauge IV—3 ft. deep; formerly cropped with maize; under the modified scheme sann hemp was grown, cut after seedling and maturity and then harvested (not incorporated in the soil).

No artificial irrigation was used. The crops in the gauges depended entirely on the rainfall in the case of *kharif* (rainy season crops) and on moisture stored in the soil and dew in the case of *rabi* (cold weather) crops. No manures were applied.

After the earthquake in 1934 the observations were discontinued. Soils, drainage water and crops were analyzed to ascertain water and crop relationships brought about by rainfall, continuous cropping without manure, fallowing and crop rotation.

* The data given in this article are extracted from a thesis by Abhiswar Sen for the Diploma Assoc. I.A.R.I.

The results obtained throw light on :

1. the quantitative and qualitative relationships between precipitation, percolation, drainage, evaporation and transpiration ;

2. the relationship between retained water and crop yields ;

3. the loss of nitrogen as nitrate through drainage and the effect of crop thereon ; and

4. the question whether productivity can be maintained at a reasonable limit without manuring but with crop rotations alone.

Rainfall percolation and evaporation

Appendices I, II and III show (*a*) the yearly and monthly rainfall for the period of study ; (*b*) the total amounts of yearly rainfall and drainage ; and (*c*) rainfall-percolation ratios for the different gauges. These statements, as would be expected, show that (*a*) percolation generally varied with rainfall, (*b*) drainage from a shallow gauge was more than that from a deeper gauge, (*c*) drainage from a gauge without crop was generally more than that from the gauge with crop, and (*d*) drainage from the gauge with a single crop was more than that from the double cropped gauge. The general relationship between rainfall and percolation is clearly brought out by the ratios for rainfall/percolation (Appendix III). The higher the ratio the less is the percolation, and on this basis it would appear that the effect of growing crop is to decrease percolation. This relationship is, however, only general. With the exception of the fallow gauge (Gauge III) where the rainfall-percolation ratio is fairly constant, similar ratios for the remaining gauges show wide fluctuations, and the effect of the crop was in some years to increase the amount of water drained away, as can be seen from Table I.

Table I

Percolation in inches

Year	Rainfall in inches	Percolation in fallow (Gauge III)	Percolation in sunn-hemp (Gauge IV)
1918	60·72	24·44	27·35
1920	47·50	12·01	13·00
1922	62·96	18·13	20·20
1924	54·18	23·03	24·16
1928	53·38	12·76	13·63
1931	43·50	11·91	15·01

In the years under consideration the rainfall varied between 47 and 60 in. The mechanical composition of the soils of the two gauges is not such as to warrant the differences in percolation. Nor can this be due to root channels or as suggested by Russell [1907-08], to the oxidation of organic matter (exclusively given by the crops grown on them) and the consequent increase in the permeability of the soil. If it is due to the soil it should be seen in the other years also. Velbel [1900] in America obtained similar results. In his studies 24 per cent of rain passed through a lysimeter of 20 cm. depth while 35 per cent went through one with double the depth. In Craibstone drain-gauges in Scotland Hendrick [1921] found that in January and February the drainage either equalled or even exceeded the rainfall. Since the water requirement of crops were different under different weather conditions and since the temperature and humidity affecting direct evaporation varied from month to month (Table II), the R/P (rainfall/percolation) ratio varied at different seasons in the gauges at Pusa, as in the case of Deherain's experiments in France [1891-92].

Table II

Mean R/P ratio in different months within a year at Pusa

Months	R/P in Drain gauge I	R/P in Drain gauge II	R/P in Drain gauge III	R/P in Drain gauge IV
June	21·53	8·67	6·99	3·22
July	3·33	5·87	4·96	11·58
August	6·03	4·87	2·04	4·84
September	6·12	10·73	4·36	5·34
October	11·04	130·00	5·51	..

The probable explanation, therefore, is that due to high humidity in the atmosphere, evaporation and transpiration were considerably reduced on certain days in the rainy months and this condition resulted in greater percolation than the usual and this was more evident in the shallow cropped gauge.

Nitrate losses in the drainage

Nitrification is exceedingly active in the surface layers of Pusa soils during the early stages of the monsoon, during breaks in the monsoon and soon after the cessation of rainy season. Comparatively little nitrification takes place during the periods of rainfall when the ground is saturated with moisture and consequently the total amount of nitrification fluctuates considerably according to the character of the monsoon. The greatest quantity of nitrate is produced in the monsoons when there are breaks in the rainfall accompanied by clear hot weather and nitrate production is least when the rainfall is evenly spread and the breaks are of short duration. In conformity with these variations the greatest

losses of nitrogen occur when periods inducing high nitrification are followed by bursts of heavy rainfall. The estimation of the losses of nitrogen as nitrate in the drainage waters was, therefore, confined to the monsoon period. The amounts of nitrate nitrogen lost per acre in drainage during the 20 years are given in Appendix V. The average values for nitrate nitrogen in kilograms per acre lost through drainage during 20 years in the different Pusa drain-gauges are given below:

Drain gauge	*Nitrate nitrogen kg. per acre*
I (Wheat only)	4·51 ± 0·86
II (Wheat and sunn-hemp)	5·49 ± 1·56
III (Fallow)	14·30 ± 1·30
IV (Sunn-hemp only)	12·72 ± 1·92

The loss of nitrates from the soil into the drainage waters was more in the shallow gauges than in the deep ones. It is the highest in the bare fallow gauge, 3 ft. deep (No. III). Next in order comes the 3 ft. deep gauge cropped with sunn-hemp (No. IV); gauge No. II, 6 ft. deep and cropped with wheat and sunn-hemp, comes next. The least loss of nitrate-nitrogen occurred in gauge No. I growing wheat only. The results are in accordance with those obtained by Burt at the Cawnpore Agricultural Station in 1916. In his results nitrate loss bore no relationship either to rainfall or to drainage. The amounts removed from the fallow gauge, though distinctly lower in two years of markedly deficient rainfall, were otherwise constant. Deherain had shown in 1895 that in shallow gauges nitrogen losses were about 30 times as great as in cropped soils. Later in 1897 he found that the total amount of nitrogen lost through crops and through drainage was only 94 kg. per acre while the loss from drainage only in the fallow gauge was 200 kg. This discrepancy he ascribed to the insufficiency of moisture for active nitrification in the cropped soil.

The nitrate content of the drainage depends on the season when nitrification is active. The amount of drainage in inches per month in a year and the nitrogen carried with it is given in Appendix VI. The irregularity in the content of nitrate-nitrogen as the consequence of irregular nitrification is evident from the statement. July, August and September are the months when rainfall was large and the drainage was also correspondingly large. The rainfall in the month of June and October is not usually large although there were occasions when heavy falls occurred. Taking the monthly means of the results for the 20 years given in Appendix VI, the amount of nitrate-nitrogen per inch of drainage can be expressed as follows (Table III):

TABLE III

Rate of drainage of nitrogen (in lb. per acre) per one inch percolation in the monsoon months of an average year at Pusa

Months	Drain-gauge I (wheat)	Drain-gauge II (mixed)	Drain-gauge III (fallow)	Drain-gauge IV (sunn-hemp)
July	0·68	2·45	2·82	3·32
August	0·81	2·09	2·02	3·32
Septr.	1·21	2·32	2·02	0·93
Octr.	3·83	1·80	3·69	No drainage

The results are interesting particularly because of their derivation from a long series of observations over a number of years and seasons. If the results for the fallow-gauge (No. III) are considered as the condition of the monsoon rains, nitrification is very vigorous and slows down in the next two or three months. About October is the period most conducive for active nitrification, i.e. after the rains have ceased. In gauges II and IV where sunn-hemp was the crop, the relationship between the crop and nitrate-nitrogen is not clear but confusing. In gauge IV active nitrification is in evidence and it would appear that the nitrates formed were not all taken up by the crop as it grew. This is more clearly seen in the results for individual months and years given in Appendix VI. The results for gauge II, in which also sunn-hemp was growing, are also of a nature similar to those for gauge IV; this is more clearly seen when the results for July, August and September (the period when sunn-hemp was growing) are compared with those for gauge I where sunn-hemp was not growing (and therefore practically the same conditions exist as in fallow gauge III between April and October) and of gauge III which was fallow. In gauge I which was kept fallow in summer and rainy season and wheat was grown in cold weather, loss of nitrate-nitrogen occurs in the month of October (the month for sowing wheat).

The field investigations by W. H. Harrison at Pusa between the years 1922 and 1926 provide confirmation and amplification of the results of drain-gauge studies in respect of nitrate loss through drainage in soils. In these investigations soil borings were taken to a depth of 9 ft. at six inch intervals and the nitric nitrogen and moisture were determined in each sample. From the data obtained it is possible to make an estimate of the amount of nitrogen which is removed from the soil through the action of drainage. For purposes of comparison the soil layers to a depth of 3 ft. are referred to as the soil (as they are subject to root action) and any nitrate washed below this

point is to be considered as lost as all the evidence obtained goes to show that it never again comes within the range of the crop.

Losses from fallow and pasture

The estimated losses in lb. per acre of nitrogen through drainage from fallow land and pasture for the monsoon periods of the years 1924, 1925 and 1926 at Pusa are given below :

	1924	1925	1926
Fallow cultivated land .	63·39	130·87	119·12
Pasture land . . .	14·76	4·33	8·77

It would appear that losses approximating to about 100 lb. nitrogen per acre may be expected from fallow land during an ordinary monsoon. On the other hand, the presence of a grass crop leads to this loss being reduced to about 10 lb.

The character of the subsoil, however, has a marked influence upon the losses from fallow lands. The examples given above referred to fairly open well-drained soils but quite different results were obtained in 1923 with a field in which the subsoil is very heavy and drainage slow. In this case, up till the middle of September the loss of nitrogen through drainage was only 46·53 lb. per acre but afterwards there was a marked increase of nitrate (49·44 lb.) in the soil. The subsoil however showed an additional loss of 14·6 lb. making a total loss of 61·13 lb.

Loss after green manuring

In 1922 green manure (sunn-hemp) was ploughed in about the beginning of September and this was followed by an increase of 26·90 lb. of nitric-nitrogen in the soil and 41·71 lb. in the subsoil. The latter was due to washing down of the nitrate from the soil and to this must be added 7·12 lb. of nitrogen which disappeared from the subsoil in the lower strata. The total loss which could be demonstrated therefore amounted to 48·83 lb. nitrogen. This was derived from the green manure crop.

Loss from cropped lands

Comparative studies (as shown below) were made in two fields, one very heavy land and the other an open porous soil, during the years 1922 and 1923. The monsoon in 1922 was good and well distributed whereas that of 1923 was broken and poor.

	1922	1923
Heavy soil	30·35	78·90
Light soil	48·14	35·64

In these conditions the loss of nitrogen from the soil through drainage occurred mainly in the first month after the onset of the monsoon and before the crop was established. In heavy monsoons later losses could only be demonstrated from the fluctuations occurring in the subsoil, i.e. soil below 3 ft.

Losses during dry season

In these conditions there is little movement of water from the soil into the subsoil and the decrease of nitrogen in the soil must be ascribed to the crop. Consequently, attention has to be directed to the removal of nitrate from the subsoil due to drainage induced by the lowering of the water-table.

	1922	1923
Light soil fallowed	..	25·71
Light soil cropped	26·00	..
Heavy soil cropped	26·08	39·95

The loss during the period appears to be independent of the cultivation and cropping and amounts to about 30 lb. per acre.

In fallow cultivated land the loss of nitric-nitrogen through drainage each year appears to vary from about 90 to 150 lb. according to weather conditions and the type of soil. This loss is reduced by the presence of a crop, but even so, and at a conservative estimate, the total annual loss cannot be less than 50 lb. per acre. The losses are least when the soil is under permanent grass.

The observations of Somers-Taylor and Ghosh [1923] on the variations in the nitrogen contents of Bihar soils, of Meggitt [1914; 1923] in Assam on the losses of soil nitrogen during the rainy season, the studies by Clark et al. [1922] on the nitrogen fluctuations in the Gangetic alluvium of the United Provinces, the studies by Narasimha Ayyangar [1936-37] in Mysore, and the investigations of Annett, Aiyar and Kayasth [1928] in the Central Provinces, provide further confirmation to the foregoing results. They studied the nitrate content of black cotton soils through two years at Nagpur and showed that nitrates were formed during the period of rains in the months of June and July but were lost during the heavy rains in the month of August. The nitrate content of the soils subsequently remained at a low level for several months. From analyses of drainage and well water, some of the nitrate lost could be accounted for in the increased nitrate contents. Harrison and Ayyar [1913-14] investigated nitrogen loss from paddy soils under swamp conditions and Viswanath [1937] studied nitrogen losses under garden soil conditions and showed that loss of nitrogen occurs from soils also in ways other than through drainage.

Soil-water and crop relationships

The yearly rainfall, the amount of water lost, the amount of water retained by the soils in the different drain gauges (the amount obtained as the difference between the rainfall and the sum of water lost by percolation and overflow) and the amount of crop produced in the different gauges are given in Appendix IV and are also shown graphically in Fig. 1.

There is a certain amount of relationship between the water retained by the soils of the drain gauges and the total crop dry matter so produced. It may again be mentioned here that in all the 20 years, neither manure nor artificial irrigation was applied to the soils in the different drain gauges. Taking the averages of the 20 years' results given in Appendix IV the relationship can be summarized as shown in Table IV.

The results for the cropped drain gauges show, as would be expected, that the yield increases with the amount of water retained. Comparing the figures for the two shallow gauges (Nos. III and IV) with those for the deeper gauges (Nos. I and II) it would appear that the efficiency of water utilization, as indicated by dry matter production, was not greater in the deeper soils than in the shallow soils. The results for the fallow drain gauge No. III show that the Pusa soil can hold nearly 30 in. of rain water through a depth of 3 ft. and it may be stated that, having regard to the minimum moisture content of the soil in the dry season, the amount of water lost by evaporation from a bare fallow soil is of the order of 30 in. per annum.

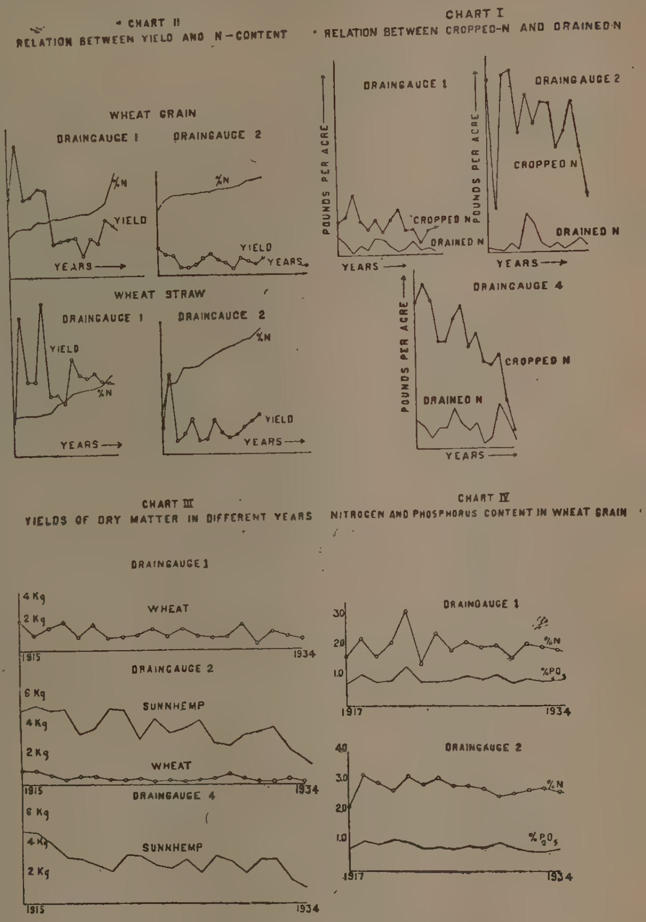

Fig. 1

Table IV

Retained water and yield of dry matter

Drain gauge No.	Average amount of rain water retained in inches	Yield kg.	Crop
I . .	32·7±0·79	1·20±0·12	Wheat
II . .	38·3±1·32	4·05±0·31	Sunn-hemp and wheat
III . .	29·2±0·59	..	Bare fallow throughout
IV . .	33·8±1·07	2·94±0·22	Sunn-hemp only

Soil nitrogen and crop nitrogen

The amounts of nitrogen contained in the crop grown in the different drain-gauges during the 20 years are given in Appendix VII. As is to be expected, the largest amount of nitrogen is due to sunn-hemp and wheat grown in gauge II. The next is due to sunn-hemp grown in gauge IV. The least is contained in the wheat crop grown in gauge I. The average nitrogen content in gm. per year for the different gauges are:

Gauge I . . .	Wheat . .	9·81 gm.
Gauge II . . .	Wheat + sunn-hemp	48·44 gm.
Gauge IV . .	Sunn-hemp .	31·05 gm.

The annual average values for the amounts of nitrogen removed in the crops and in the drainage, calculated as kg. per acre are given in Table V.

TABLE V

Nitrogen removed annually in crop and in drainage in kg. per acre

Mean nitrogen removed by	Wheat drain gauge	Wheat and sunn-hemp drain gauge II	Fallow drain gauge III	Sunn-hemp drain gauge IV
Crop . . .	9·81	48·44	...	31·05
Drainage . .	4·51	5·49	14·30	12·72
Total removal .	14·32	53·93	14·30	43·77

The above results are of interest. The amounts of nitrogen lost from gauges I and III are of the same order. On the assumption that wheat plant takes its nitrogen as nitrates resulting from nitrification and that the figure for the fallow-gauge III represents all the amount of nitrate produced, it would appear that nitrification proceeds at the same rate in Pusa soil, whether cropped or uncropped, provided no extraneous applications of manures are made. This is in agreement with Deherain's observation as long ago as 1895.

A point of considerable theoretical and practical interest is the large amount of nitrogen that is found in the crop and in the drainage in spite of the fact that manure was never applied to any of the drain gauges. The question is where does this nitrogen come from. It should be due to the fixation of atmospheric nitrogen as one would expect in the case of a leguminous crop. In regard to fixation of nitrogen by the crops, it is understandable in the case of the leguminous crop sunn-hemp, but the doings of the wheat crop are not clear. The results of gauge II in which both sunn-hemp and wheat were grown, the amount of nitrogen contained in the crop was 48·44 kg. per acre as against 31·05 kg. in the sunn-hemp crop in drain-gauge IV, i.e. the nitrogen on account of wheat crop is therefore (48·44—31·05) 17·39 kg. This figure does not agree with 9·81, the value for wheat in gauge I, where only wheat was grown. The average value for wheat in gauge II is only 3·55 kg. It is thus not clear to what extent wheat in gauge II was benefited by the sunn-hemp that preceded wheat, or to what extent the wheat crop depended on its own resources. Comparing gauge I (wheat only) with gauge III (fallow) the total amount of nitrogen removed in the drainage and in the wehat crop is of the same order, the values being 14·32 and 14·30 kg. respectively for gauges I and III.

NITROGEN IN DRAINAGE AND IN THE CROP

The foregoing results obtained over a long period of years are in agreement with those recorded by Leather [1911] for a shorter period in respect of he observation that the amount of nitrates in drainage waters from the cropped gauge is very much less than from that from the fallow lands. This is attributed to the absorption of the nitrate by the growing crop. The question that can reasonably arise is that if crop plants take nitrogen in the form of nitrates, what is the significance of loss of nitrate-nitrogen either through drainage as such and where drainage is not enough or possible by denitrification. That is a question raised by Viswanath [1937]. The question is too large and too involved to be discussed in this paper, but an examination of the relationship between loss of nitrate-nitrogen in the drainage and crop production and/or nitrogen contained in the crop throws some light on the subject. The amounts of nitrogen in the drainage and in the crops from the different drain gauges are plotted in the curves in Fig. 1. The character of the curves for gauge I show a general parallel relationship in some years and an inverse relationship in others. The indication generally in the case of wheat is that with the increase of nitrate-nitrogen in the drainage the amount of total nitrogen contained in the crop decreased. Similar is the relationship between drainage nitrogen and total nitrogen for mixed crops in gauge II. The relationship is generally inverse and indicates absorption of nitrates by the crops. The curves for gauge IV show a more consistent relationship indicating that, as drainage increases, that is, as the loss of nitrates through drainage increased, the gain in the crop also increased. The contrast between the relationships in gauge I and those for gauges I and II is probably due to the differences in the gauges. It is possible that in gauges I and II also the nitrate moved lower than 3 ft., and although it had not passed into the drainage, the result of its retention below 3 ft. was in effect similar to that in the 3 ft. deep gauge IV. This view derives support from the results given in Table VI, which show the nitrogen content at different depths.

TABLE VI

Percentage nitrogen in soil

Depth in ft.	Initial	Gauge I	Gauge II	Gauge III	Gauge IV
1	0·06	0·04	0·04	0·03	0·05
2	0·05	0·03	0·03	0·02	0·03
3	0·02	0·02	0·03	0·02	0·02
4	0·02	0·02	0·02	...	...
5	0·02	0·02	0·02	...	...
6	0·02	0·02	0·02	...	...

It would, therefore, appear from these results and the nitrogen estimations made by Harrison

that the loss of nitrogen through drainage is not merely a mechanical removal and has some biochemical significance in the nitrogen metabolism of crop plants.

Nitrogen balance in the soils and nitrogen turn-over in the crops

The figures in Table VII give an idea of the nitrogen balance in the soils of the different drain gauges, calculated from the differences between the initial nitrogen contents of the soils when the experiment was started in 1905 and the final nitrogen values of the soils when the experiment was closed in 1934, i.e. over a period of 30 years. Unfortunately, figures for annual or periodical determinations of the nitrogen contents of the soils are not available. Such data would have provided information on the fluctuations, if any, in the nitrogen contents of the soils, and on the rate of their nitrogen exhaustion.

TABLE VII

Loss or gain of nitrogen in the different layers of soil in lb. per acre over a period of 30 years of cropping

Depth	Drain Gauge I	Drain Gauge II	Drain Gauge III	Drain Gauge IV
1st foot	(—) 480	(—) 480	(—) 720	(—) 240
2nd foot	(—) 480	(—) 480	(—) 720	(—) 480
3rd foot	...	(+) 240	...	...
Total loss	(—) 960	(—) 720	(—) 1440	(—) 720
Annual average loss	(—) 32	(—) 24	(—) 48	(—) 24

It is seen that in all the gauges there had been loss of nitrogen from the soil. Except in the case of drain gauge II the loss of nitrogen is confined to the top 2 ft. layers of the soil. The loss was the greatest in the fallow gauge III. The next highest loss was in gauge I, which was kept fallow in the rainy season, and cropped with wheat in the cold weather. The losses were least in gauges II and IV, the loss being greater in gauge II than in gauge I and confined practically to the first foot layer of the soil. The losses in gauges II and IV were of the same order, and were less than the other two gauges. Two indications come out of these data. One is that the loss does not appear to depend upon the depth of the gauge and the other is that the leguminous crop, sunn-hemp had contributed to the reduction in the losses although the mere growing of the leguminous crop could not maintain the original nitrogen level.

If the annual turnover of nitrogen in the crops grown in the soils is considered, we get the following average values of nitrogen, in pounds per acre, contained in the crops for the four different gauges (Table VIII).

TABLE VIII

Annual loss of nitrogen from Pusa soil

——	Drain gauge I	Drain gauge II	Drain gauge III	Drain gauge IV
Nitrogen in drainage in lb. per acre per year	9·95	12·10	31·45	27·98
Nitrogen removed in crop per acre per year	21·58	106·57	...	68·31
Annual average loss (sum of N drained and N removed by crop)	31·53	118·67	31·45	96·29
Annual average loss (from difference in initial and final N in soil)	32·00	24·00	48·00	24·00

Looking at the figures for the amount of nitrogen removed in crops and at the figures for the net loss of nitrogen, and considering the large amount of nitrogen in the crop and the comparatively smaller net losses of nitrogen, it is evident that nitrogen fixation by crops was taking place ; and having regard to the loss of nitrate-nitrogen in the drainage, the conclusion is irresistible that fixation of nitrogen and nitrification and loss were taking place. This observation lends support to those of Annett, Aiyar and Kayasth [1928] and of Viswanath [1937; 1937]. The latter showed that the processes of nitrification, nitrogen loss and nitrogen fixation occur in regular sequence. The results of the drain gauge studies further show that growing of legumes without incorporating them into the soil does not add to the total nitrogen reserves in the soil.

Crop yields in relation to nitrogen

The observation that has just now been made derives further support from the results of crop yields. That crop yields are proportional to the amount of retained water, is already seen. A statement of the yields of crops during the 20 years and their chemical analyses is given in Appendices IX and X ; the curves in Chart III (Fig. 1) show the annual yields. The yields of wheat do not show gradual decrease even when no manure was applied. The effect of growing sunn-hemp and its removal does not appear to have benefited the following wheat crop. The effect, if any, appears to be an adverse one judging from the yields of wheat when grown alone and after sunn-hemp. The yield of sunn-hemp in gauge II where two crops (wheat—sunn-hemp) were grown, was more than that in gauge IV where sunn-hemp alone was grown. The differences in the depths of soils, and the increased

availability of supplies of plant food in the deeper gauge might be responsible for the differences in the yield of sunn-hemp crop in the two gauges. As for wheat in drain gauge II, where the yield of wheat after sunn-hemp was lower than that in gauge I, growing wheat only, the decrease in crop yield appears to be due to the effect on growth in general, and the mean percentage of grain to the total crop is 33 and 29 per cent for gauges I and II respectively.

If the yields and their corresponding percentages of nitrogen are compared it will be seen that, though the yield of wheat in drain gauge II is less, it is richer in its nitrogen content. This is so not only in the case of grains but also in the case of straw and chaff. The results are illustrated in Table IX and in chart II (Fig. 1).

TABLE IX

Percentage of nitrogen and yield of wheat grown singly and in rotation with sunn-hemp

Crop portion	Drain gauge I (wheat only)		Drain gauge II (wheat in rotation with sunn-hemp)	
	Yield in kg.	N_2 per cent	Yield in kg.	N_2 per cent
Stalk .	$0 \cdot 56 \pm 0 \cdot 05$	$0 \cdot 36 \pm 0 \cdot 02$	$0 \cdot 21 \mp 0 \cdot 04$	$0 \cdot 62 \pm 0 \cdot 04$
Chaff .	$0 \cdot 13 \pm 0 \cdot 01$	$0 \cdot 45 \pm 0 \cdot 03$	$0 \cdot 06 \pm 0 \cdot 005$	$0 \cdot 80 \pm 0 \cdot 05$
Grain .	$0 \cdot 33 \pm 0 \cdot 04$	$1 \cdot 98 \pm 0 \cdot 13$	$0 \cdot 12 \pm 0 \cdot 01$	$2 \cdot 81 \pm 0 \cdot 06$

Yield and nitrogen content of crop have not gone parallel but varied inversely.

It has been seen that the yield of crops in the soils never manured with any kind of fertilizer, did not decrease continusously but varied irregularly. The composition of the wheat grain however, did not suffer by continuous cropping and consequent exhaustion of the soil. The variation is rather irregular. If the quality of a cereal is judged by its nitrogen, potash and phosphoric acid contents, then the wheat grains in the drain gauges maintained their quality constant within reasonable limits throughout the end of 20 years. The tabular statements in Appendix and the curves in chart IV (Fig. 1) illustrate the point in respect of phosphoric acid and potash.

Turning now to the sunn-hemp crop, it will be seen that the yields in contrast to those of wheat, show a distinct decrease with the lapse of years. This decline in yield is clearly seen from the curves in chart IV (Fig. 1). Why this should be so in the case of sunn-hemp and not in the case of wheat, it is difficult to say. It might possibly be due principally to graduall depletion of mineral nutrients available to the sunn-hemp crop. Neither the chemical analysis of the soils nor the percentage composition of the crops in successive years indicates deficiency or decrease in phosphoric acid and potash; but a comparison of the average amounts of these constituents removed in the crop in the first four years, and the last four years, indicates the extent of mineral depletion during the 20 years, as will be seen from Table X.

TABLE X

Average quantities in gm. of potash (K_2O) and phosphoric anhydride (P_2O_5)

	Gauge I		Gauge II		Gauge IV	
	K_2O	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5
Average for the years 1915-18	$16 \cdot 2$	$4 \cdot 9$	$56 \cdot 2$	$6 \cdot 8$	$40 \cdot 2$	$4 \cdot 6$
Average for the years 1930-34	$9 \cdot 4$	$2 \cdot 6$	$33 \cdot 1$	$3 \cdot 9$	$13 \cdot 1$	$1 \cdot 9$

The crop evidently adjusted themselves to the growing depletion in mineral supplies by restricting quantitative growth to use the available mineral supply for the requirements of normal composition.

In regard to the nitrogen content of the sunn-hemp crops grown in drain gauges II and IV, the nitrogen percentage of seeds remains practically constant throughout the years, though for a few years in the beginning it was comparatively less. The mean amount of nitrogen is about $6 \cdot 23$ per cent. The amount of nitrogen in leaves is about three times the amount in stalk and this ratio, though varying within certain limits remains remarkably constant. This shows that the distribution of mineral or organic mitrogen in various parts of the plant remains undisturbed by varying conditions of rainfall, drainage and other factors. The nitrogen contents of the pods without seeds is quite variable; the variation being between percentages $2 \cdot 782$ and $0 \cdot 869$.

SUMMARY

Twenty years' data on the drain gauge or lysimeter studies at Pusa show:

Percolation varies almost directly as the precipitation.

Loss of nitrate-nitrogen through drainage can attain a value of 100 lb. per acre. The maximum loss occurs during rainy months.

The presence of crop decreases the amount of drainage and loss of nitrogen and mineral matter through drainage and checks direct evaporation from soil.

The amount of direct evaporation from soil at Pusa is about 30 in. per year.

Yields of crops are proportional to the amount of water retained by the soil.

On the soils of the drain-gauges at Pusa, continuous cropping without manure did not result in decrease of yields of wheat, but the yields of sunn-hemp showed definite decrease.

In the case of wheat the relationship between yield and nitrogen content of the grain is an inverse one and the same is observed in the case of sunn-hemp also.

The yields of wheat with a *kharif* fallow were higher than the yields of wheat in rotation with sunn-hemp, which was not incorporated into the soil, thus showing that mere growing and removal of leguminous rotation crop will not be of much benefit to the succeeding crop.

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Appendix I

Rainfall in inches at Pusa in different years for the period under review

Month	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
January	0·13	...	0·13	...	1·29	...	0·51	0·41	0·03	0·03	0·66	0·86	0·51	1·28	1·25	0·37	0·10	...	0·02	...
February	1·73	0·44	0·75	...	0·02	1·70	...	0·45	2·53	0·22	...	...	1·47	0·52	...	0·35	0·95	...	0·55	...
March	1·31	...	0·32	0·09	0·02	1·11	0·32	...	...	...	...	0·26	0·94	...	1·27	0·42	0·26	0·04	...	...
April	0·26	0·31	...	0·69	1·36	...	0·69	0·18	0·30	0·01	1·35	0·43	0·01	0·03	0·19	0·14	...	0·16	1·33	...
May	1·99	0·37	3·48	3·69	0·68	0·40	1·34	0·28	1·03	0·13	1·20	0·60	2·14	1·25	0·49	0·97	1·02	6·65	4·37	...
June	5·07	9·67	7·96	11·50	2·21	4·48	4·06	20·03	2·78	4·72	4·97	0·83	7·09	3·07	6·47	5·61	1·41	5·90	8·25	...
July	16·25	15·85	12·51	11·64	14·78	12·02	8·09	18·56	6·42	28·86	9·10	16·48	12·17	13·27	8·96	6·26	27·87	7·09	20·01	16·27
August	21·97	13·90	5·35	26·65	5·54	7·99	12·73	12·76	8· 8	8·09	15·78	11·32	7·94	25·12	9·78	5·18	5·05	7·85	10·61	9·21
September	4·67	10·62	10·77	6·43	5·11	16·90	12·51	8·33	5·72	17·38	16·38	5·75	4·71	2·52	10·05	11·86	2·49	0·58	8·21	4·50
October	0·93	4·95	1·88	...	1·89	...	1·10	1·30	0·98	0·53	0·17	0·06	0·26	6·21	10·51	1·81	4·06	2·52	2·15	...
November	0·56	...	...	...	...	...	...	0·60	...	2·21	0·17	...	1·92	...	...	0·45	0·03	0·30	...	...
December	0·02	...	0·01	...	0·02	...	0·01	0·06	0·01	...	...	0·23	...	0·21	2·15	0·51	...	...	...	...
Total	54·89	56·11	43·16	60·72	32·92	47·50	41·36	62·96	28·38	54·18	49·78	36·82	39·16	53·38	51·12	33·93	43·50	31·35	55·50	43·36

Appendix II

Rainfall and percolation in different gauges in inches

Year	Annual rainfall	Percolation in			
		Drain gauge I (Wheat) (6 ft.)	Drain gauge II (Wheat & sunn-hemp) (6 ft.)	Drain gauge III (Bare fallow) (3 ft.)	Drain gauge IV (Sunn-hemp) (3 ft.)
1915	54·89	9·83	11·90	18·70	13·82
1916	56·11	20·51	6·89	26·34	18·04
1917	43·16	8·95	1·01	11·95	3·21
1918	60·72	21·30	20·03	24·44	27·35
1919	32·92	1·95	..	5·35	1·05
1920	44·60	9·15	6·97	12·01	13·00
1921	41·36	9·39	4·12	13·12	11·49
1922	62·96	24·42	20·34	28·13	28·20
1923	28·38	..	..	..	..
1924	54·18	18·77	14·24	13·03	24·16
1925	49·78	12·39	11·50	17·18	16·45
1926	36·82	3·40	1·82	8·82	7·70
1927	39·16	2·49	..	7·48	3·99
1928	53·38	8·47	8·85	12·76	13·63
1929	51·12	13·48	2·65	15·81	7·19
1930	33·93	2·80	..	5·16	0·98
1931	43·50	10·36	10·84	11·91	15·01
1932	31·35	..	..	..	..
1933	55·50	15·51	6·46	18·06	16·44
1934	43·36	9·57	3·83	12·78	6·91

Appendix III

Rainfall-percolation ratios of Pusa soil in different years

Year	Rainfall in inches	Rainfall/percolation ratio in			
		Drain gauge I	Drain gauge II	Drain gauge III	Drain gauge IV
1915	54·89	5·6	4·6	2·9	3·9
1916	56·11	2·7	8·1	2·1	4·3
1917	43·16	4·8	42·7	3·6	13·4
1918	60·72	2·8	3·0	2·4	2·2
1919	32·92	16·9	..	6·1	3·1
1920	47·50	4·8	6·4	3·7	3·4
1921	41·36	4·4	10·4	3·1	3·6
1922	62·96	2·6	3·1	2·2	2·2
1923	28·38	..	..	..	..
1924	54·18	2·9	3·8	2·4	2·2
1925	49·78	4·0	4·3	2·9	3·0
1926	36·82	10·9	20·2	4·2	4·9
1927	39·16	15·8	..	5·2	4·3
1928	53·38	6·3	6·0	4·2	3·9
1929	51·12	3·7	19·3	3·2	7·1
1930	33·93	12·1	..	6·6	34·6
1931	43·50	4·2	4·0	3·7	2·9
1932	31·35	..	..	..	..
1933	55·50	3·6	8·6	3·1	3·3
1934	43·36	4·5	11·4	3·4	6·3

Appendix IV

Retained water in inches and dry matter produced in kg.

Year	Drain gauge I (wheat)		Drain gauge II (Wheat & sunn-hemp)		Drain gauge III (Bare fallow)		Drain gauge IV (Sunn-hemp)	
	Retained water	Dry matter	Retained water	Dry matter	Retained water	Dry matter	Retained water	Dry matter
1915 . . .	41	1·99	43	6·18	36	..	41	4·79
1916 . . .	32	1·45	49	0·91	28	..	43	4·80
1917 . . .	34	1·89	42	5·70	31	..	40	3·98
1918 . . .	33	0·90	41	5·39	28	..	33	3·07
1919 . . .	30	1·73	31	3·85	28	..	32	3·03
1920 . . .	35	..	38	3·78	28	..	32	2·63
1921 . . .	30	0·70	37	5·42	27	..	30	2·17
1922 . . .	30	0·86	43	5·26	28	..	35	3·28
1923 . . .	28	1·18	28	3·54	28	..	28	3·19
1924 . . .	31	1·22	40	4·54	28	..	29	2·62
1925 . . .	34	0·87	38	3·82	28	..	33	2·40
1926 . . .	31	1·39	35	4·02	26	..	29	2·98
1929 . . .	36	0·89	39	4·50	31	..	35	2·09
1930 . . .	30	1·68	34	3·74	28	..	34	2·89
1931 . . .	30	0·43	32	3·67	26	..	28	3·03
1932 . . .	31	1·64	31	4·04	31	..	31	3·01
1933 . . .	38	0·87	49	2·80	32	..	39	1·57
1934 . . .	34	0·67	40	1·83	31	..	36	1·31

Appendix V

Nitrate nitrogen in kg. per acre lost through drainage during 20 years

Year	Drain gauge I (Wheat)	Drain gauge II (Wheat and sunn-hemp)	Drain gauge III (Bare fallow)	Drain gauge IV (Sunn-hemp)
1915	12·78	2·94	23·35	19·11
1916	8·15	2·09	24·49	15·24
1917	0·89	0·55	15·04	6·93
1918	6·01	10·97	17·53	13·62
1919	0·89	..	12·22	2·52
1920	2·22	8·91	21·63	19·94
1921	3·12	2·39	14·85	14·21
1922	11·12	27·16	16·49	26·77
1923	No drainage	No drainage	No drainage	No drainage
1924	9·90	19·19	17·06	17·37
1925	5·29	6·37	11·76	11·65
1926	2·03	2·91	15·00	16·81
1927	0·62	..	9·92	8·38
1928	4·01	5·38	9·00	3·29
1929	9·46	2·10	16·66	7·18
1930	3·12	..	8·79	0·91
1931	3·31	5·08	22·25	30·61
1932	0·40	..	5·60	..
1933	4·43	9·31	13·81	9·61
1934	2·43	3·99	10·51	8·57
Total	90·22	109·94	286·01	235·83
Mean per year . . .	4·51	5·49	14·30	12·72

Appendix VI

Relation between drainage of water (in.) and drainage of nitrate-nitrogen in lb. per acre

Month	Year	Drain gauge I		Drain gauge II		Drain gauge III		Drain gauge IV	
		Drainage	Nitrogen	Drainage	Nitrogen	Drainage	Nitrogen	Drainage	Nitrogen
June .	1922	0·93	1·19	2·31	3·27	2·87	9·32	6·21	23·91
July .	1919	..	..	..	..	1·41	5·17	0·66	3·99
	1922	10·88	9·92	12·76	45·05	12·63	17·14	14·53	30·78
	1924	5·14	3·19	1·59	2·52	8·29	27·69	10·00	28·76
	1926	..	..	..	..	..	..	0·95	4·08
	1927	..	..	..	..	1·67	3·85	0·05	0·05
	1929	..	..	..	..	..	0·02	..	..
	1931	6·62	3·64	9·16	8·95	9·13	42·57	14·02	61·27
	1933	5·36	2·9[illegible]	2·66	5·91	7·29	22·79	10·74	40·90
	1934	3·43	2·43	1·65	2·84	6·34	13·25	4·85	15·74
August .	1919	..	..	..	..	0·98	0·59	..	..
	1921	0·64	0·27	..	..	4·41	17·93	2·48	13·82
	1922	7·77	3·59	11·19	8·80	3·70	..	6·61	4·11
	1924	4·01	4·96	3·33	7·94	4·31	3·22	3·40	5·19
	1925	5·60	2·36	1·74	3·89	8·04	18·93	6·26	20·73
	1926	1·35	1·97	1·21	4·54	6·47	27·51	4·58	28·42
	1927	1·35	0·58	..	..	4·65	14·14	3·94	18·39
	1928	7·69	6·83	8.35	12·93	11·54	18·60	13·64	7·24
	1929	1·14	2·16	..	..	3·69	10·09	0·44	0·63
	1931	2·96	3·01	1·68	2·83	2·73	4·71	1·49	3·30
	1933	5·74	2·31	1·21	3·05	6·25	7·05	2·24	1·73
	1934	5·08	1·95	2·19	5·95	5·20	6·35	2·06	3·12
September	1919	1·77	1·20	..	..	2·96	16·13	0·39	1·56
	1921	8·75	6·61	4·14	5·91	8·71	14·73	9·01	17·45
	1922	4·44	3·81	0·22	0·24	4·45	2·36	0·85	0·10
	1924	9·62	13·65	9·32	31·47	10·43	6·63	10·76	4·27
	1925	6·80	9·28	9·76	10·13	9·14	6·95	10·19	4·91
	1926	2·02	2·49	0·61	1·88	2·35	5·50	1·27	1·60
	1927	1·14	0·75	..	..	1·17	3·85	..	..
	1928	0·11	0·15	..	..	..	0·01	..	..
	1929	4·37	5·29	..	..	4·65	15·35	..	..
	1930	2·79	6·75	..	..	5·15	17·25	0·98	2·01
	1931	0·29	0·53	..	..	0·16	1·72	..	..
	1932	0·61	0·[illegible]0	..	..	3·62	12·34	..	..
	1933	4·11	4·44	2·59	11·52	4·58	1·55	3·46	0·61
	1934	1·06	1·11	..	..	1·25	3·64	..	..
October .	1919	0·17	0·77	..	..	..	..	..	..
	1922	0·43	0·23	0·01	0·05	0·09	3·77	..	..
	1928	0·67	1·85	..	..	1·22	1·20	..	..
	1929	1·86	13·37	2·65	4·62	..	..	..	..
	1930	2·80	6·86	..	..	5·16	19·31	..	..

Appendix VII

Nitrogen in gm. in crops grown on the drain gauges

Year	Drain gauge I Wheat	Drain gauge II			Drain gauge IV Sunn-hemp
		Wheat	Sunn-hemp	Total	
1915	9·86	1·99	50·00	51·99	44·65
1916	11·33	..	..	14·19	50·62
1917	18·80	1·80	50·10	51·90	45·13
1918	10·21	1·54	56·90	58·44	32·80
1919	12·34	2·01	56·80	58·81	37·23
1920	..	..	..	38·51	33·58
1921	7·55	1·11	34·49	35·60	32·92
1922	10·36	2·82	44·55	47·37	39·63
1923	..	6·16	33·05	39·21	24·10
1924	6·85	4·23	34·93	39·16	43·64
1925	10·24	3·29	41·39	44·68	30·87
1926	14·29	4·05	40·12	44·17	35·59
1927	8·16	5·99	35·24	41·23	18·27
1928	7·33	6·46	25·73	32·19	26·43
1929	7·89	5·87	26·53	32·40	25·45
1930	11·86	2·24	30·78	33·02	20·49
1931	3·78	2·21	..	45·02	28·51
1932	..	..	..	..	..
1933	7·85	2·21	29·67	31·88	14·59
1934	7·99	4·96	12·49	17·45	5·46
Total . .	166·79	56·72	718·45	775·17	589·93
Mean per year . .	9·81	3·55	44·9	48·44	31·05

Appendix VIII

Results of analyses of HCl-extracts of soils

Depth 3 in. apart	Soils of drain gauge I			Soils of drain gauge II			Soils of drain gauge III			Soils of drain gauge IV		
	N_2 per cent.	P_2O_5 per cent.	K_2O per cent	N_2 per cent	P_2O_5 per cent	K_2O per cent	N_2 per cent	P_2O_5 per cent	K_2O per cent	N_2 per cent	P_2O_5 per cent	K_2O per cent
1	0·044	0·09	0·71	0·045	0·10	0·51	0·033	0·10	0·46	0·061	0·07	0·36
2	0·036	0·09	0·70	0·037	0·09	0·59	0·031	0·10	0·50	0·057	0·07	0·37
3	0·031	0·09	0·89	0·036	0·09	0·67	0·027	0·10	0·64	0·054	0·07	0·41
4	0·037	0·09	0·91	0·031	0·09	0·69	0·029	0·09	0·55	0·040	0·06	0·30
5	0·045	0·09	0·86	0·033	0·09	0·90	0·025	0·07	0·59	0·034	0·09	0·55
6	0·027	0·08	0·75	0·027	0·09	0·79	0·020	0·07	0·63	0·034	0·06	0·53
7	0·018	0·08	0·64	0·020	0·08	0·79	0·019	0·07	0·52	0·034	0·07	0·65
8	0·040	0·07	0·64	0·019	0·07	0·76	0·018	0·07	0·54	0·023	0·09	0·51
9	0·015	0·07	0·69	0·023	0·08	0·67	0·017	0·07	0·54	0·024	0·07	0·57
10	0·022	0·06	0·64	0·029	0·08	0·73	0·014	0·07	0·52	0·021	0·08	0·58
11	0·016	0·07	0·68	0·017	0·07	0·66	0·016	0·07	0·59	0·020	0·10	0·32
12	0·015	0·06	0·77	0·041	0·90	0·78	0·013	0·07	0·47	0·021	0·07	0·48
13	0·016	0·07	0·58	0·018	0·07	0·54	...	...	...	..	...	...
14	0·015	0·08	0·57	0·018	0·07	0·53	...	...	...	...	...	...
15	0·014	0·08	0·62	0·018	0·07	0·51	...	...	...	...	...	...
16	0·014	0·06	0·62	0·018	0·07	0·81	...	...	...	...	...	...
17	0·019	0·06	0·91	0·020	0·07	0·59	...	...	...	...	...	...
18	0·016	0·06	0·83	0·014	0·07	0·81	...	...	...	...	...	...
19	0·013	0·06	0·89	0·019	0·07	0·59	...	...	...	...	...	...
20	0·013	0·06	0·88	0·016	0·07	0·55	...	...	...	...	...	...
21	0·013	0·07	0·81	0·014	0·06	0·72	...	...	...	...	...	...
22	0·014	0·06	0·70	0·016	0·06	0·74	...	...	...	...	...	...
23	0·014	0·06	0·78	0·015	0·06	0·89	...	...	...	...	...	...
24	0·014	0·07	0·84	0·015	0·06	0·86	...	...	...	...	...	...

APPENDIX IX

Yields of crops in kg. grown in soils of the drain gauges

Year	Wheat in drain gauge I			Wheat in drain gauge II			Sunn-hemp in drain gauge II		Sunn-hemp in drain gauge IV			
	Straw	Chaff	Grain	Straw	Chaff	Grain	Stalk	Leaves	Stalk	Leaves	Pods	Seeds
1915 .	...	...	0·13	...	...	0·05	4·24	1·02	3·90	0·70	0·11	0·08
1916 .	0·81	0·16	0·48	0·50	0·11	0·30	...	...	3·70	0·67	0·21	0·22
1917 .	1·03	0·27	0·59	0·31	0·10	0·18	4·17	0·84	3·03	0·59	0·14	0·22
1918 .	0·40	0·12	0·38	0·13	0·06	0·11	3·93	1·16	2·13	0·66	0·12	0·16
1919 .	1·01	0·18	0·54	0·26	0·08	0·11	2·34	1·06	2·10	0·53	0·15	0·25
1920 .	...	...	...	...	...	...	2·97	0·81	1·72	0·60	0·11	0·20
1921 .	0·49	0·09	0·22	0·18	0·05	0·07	4·02	1·10	1·68	0·19	0·10	0·20
1922 .	0·50	0·10	0·26	0·18	0·04	0·07	3·77	1·20	2·43	0·36	0·16	0·33
1923 .	0·69	0·12	0·37	0·23	0·07	0·14	2·16	0·94	2·03	0·76	0·13	0·27
1924 .	0·50	0·18	0·54	0·11	0·03	0·04	3·30	1·06	1·49	1·09	0·02	0·02
1925 .	0·41	0·12	0·34	0·14	0·05	0·09	3·16	0·38	1·87	0·37	0·06	0·10
1926 .	0·66	0·15	0·58	0·10	0·05	0·08	2·89	0·90	2·27	0·45	0·10	0·16
1927 .	0·54	0·10	0·25	0·14	0·06	0·10	3·30	1·00	1·76	0·21	0·05	0·07
1928 .	0·56	0·03	0·24	0·23	0·06	0·15	2·48	0·34	2·77	0·34	0·07	0·04
1929 .	0·52	0·09	0·26	0·54	0·05	0·14	2·10	0·50	2·48	0·22	0·04	0·13
1930 .	0·93	0·23	0·52	0·22	0·07	0·13	2·71	0·61	1·65	0·33	0·05	0·06
1931 .	0·21	0·08	0·14	0·09	0·05	0·05	2·66	0·82	2·45	0·31	0·10	0·17
1932 .	0·81	0·19	0·64	0·09	0·07	0·04	3·03	0·81	1·98	0·81	0·08	0·14
1933 .	0·50	0·12	0·25	0·23	0·05	0·11	1·96	0·45	1·50	0·02	0·03	0·02
1934 .	0·36	0·09	0·22	0·04	0·05	0·06	1·48	0·20	0·90	0·05	0·06	0·12
Average .	0·60	0·14	0·38	0·21	0·06	0·11	2·98	0·80	2·19	0·46	0·09	0·15

APPENDIX X

Composition of crops grown in soils of the drain gauges

Percentage of nitrogen in crops

Year	Wheat in drain gauge I			Wheat in drain gauge II			Sunn-hemp in drain gauge II		Sunn-hemp in drain gauge IV			
	Straw	Chaff	Grain	Straw	Chaff	Grain	Stalk	Leaves	Stalk	Leaves	Pods	Seeds
1915 .	...	...	2·04	...	...	2·66	0·57	2·00	0·72	1·37	1·56	6·45
1916 .	0·31	0·38	1·72	0·51	0·77	2·95	0·62	2·30	0·66	1·74	1·24	5·88
1917 .	0·24	0·24	1·65	0·29	0·41	2·22	0·70	2·30	0·69	1·65	1·22	5·70
1918 .	0·29	0·39	2·27	0·73	0·99	3·21	0·70	2·12	0·61	1·40	1·36	5·73
1919 .	0·28	0·34	1·65	0·92	1·25	2·96	0·83	2·50	0·69	1·55	1·30	5·18
1920 .	...	...	...	...	...	...	0·71	2·15	0·61	1·61	1·29	6·17
1921 .	0·52	0·40	2·12	0·76	0·74	2·70	0·86	2·50	0·87	2·12	1·11	6·64
1922 .	0·27	0·61	3·17	0·28	0·64	3·17	0·51	2·10	0·47	1·67	0·87	6·37
1923 .	...	...	...	...	...	...	0·52	2·24	0·50	1·40	1·03	6·88
1924 .	0·26	0·35	1·38	0·71	0·86	2·92	0·65	2·03	0·64	1·66	1·23	6·18
1925 .	0·35	0·50	2·44	0·69	0·88	3·12	0·64	2·08	0·57	1·82	1·33	6·23
1926 .	0·42	0·58	1·84	0·63	0·91	2·87	0·74	2·23	0·66	1·78	1·39	6·97
1927 .	0·43	0·57	2·11	0·58	0·64	2·87	0·63	1·94	0·55	1·66	1·60	6·17
1928 .	0·45	0·34	1·95	0·58	0·76	2·77	0·67	2·56	0·57	1·81	2·78	6·53
1929 .	0·44	0·44	1·99	0·47	0·65	2·50	0·85	2·40	0·49	1·83	2·33	6·57
1930 .	0·26	0·53	1·61	0·76	0·86	2·64	0·53	1·99	0·91	1·63	...	...
1931 .	0·26	0·40	2·04	0·48	0·70	2·69	0·79	2·68	0·43	1·78	1·15	6·61
1932 .	...	...	...	...	...	...	0·74	2·73	0·59	2·42	1·50	6·01
1933 .	0·47	0·59	1·95	0·66	0·89	2·74	0·76	2·82	0·83	1·97	1·57	6·13
1934 .	0·38	0·44	1·85	0·59	0·88	2·65	0·72	3·02	0·45	1·55	1·17	6·05
Average .	0·35	0·44	1·99	0·61	0·80	2·81	0·69	2·34	0·63	1·72	1·42	6·23

APPENDIX X—*contd*

Composition of crops grown in soils of the drain gauges

Percentage of P_2O_5 in crops

Year	Wheat in drain gauge I			Wheat in drain gauge II			Sunn-hemp in drain gauge II		Sunn-hemp in drain gauge IV			
	Straw	Chaff	Grain	Straw	Chaff	Grain	Stalk	Leaves	Stalk	Leaves	Pods	Seeds
1915 .	...	...	0·90	...	...	0·74	0·09	0·22	0·08	0·16	0·19	0·93
1916 .	0·09	0·19	0·95	0·09	0·21	0·88	0·10	0·25	0·06	0·19	0·15	0·66
1917 .	0·05	0·12	0·77	0·06	0·19	0·77	0·08	0·22	0·06	0·15	0·12	0·59
1918 .	0·10	0·57	1·04	0·15	0·47	0·99	0·09	0·20	0·06	0·13	0·15	0·73
1919 .	0·07	0·10	0·79	0·25	0·50	0·88	0·10	0·25	0·06	0·14	0·11	0·87
1920 .	...	...	...	...	...	...	0·11	0·24	0·07	0·17	0·12	0·70
1921 .	0·08	0·15	1·10	0·14	0·19	1·04	0·11	0·20	0·10	0·28	0·13	1·12
1922 .	0·06	0·12	1·31	0·08	0·13	0·94	0·08	0·23	0·09	0·20	0·07	0·73
1923 .	...	...	...	...	...	...	0·08	0·24	0·09	0·18	0·15	1·09
1924 .	0·19	0·56	0·79	0·11	0·63	0·75	0·06	0·20	0·06	0·20	0·16	0·58
1925 .	0·11	0·39	0·79	0·13	0·17	0·79	0·06	0·24	0·05	0·21	0·17	0·77
1926 .	0·12	0·38	0·83	0·14	0·23	0·77	0·09	0·29	0·07	0·23	0·20	0·69
1927 .	0·10	0·23	0·01	0·09	0·14	0·82	0·05	0·19	0·06	0·19	0·16	0·79
1928 .	0·11	0·09	0·87	0·08	0·19	0·80	0·07	0·28	0·05	0·21	0·30	0·69
1929 .	0·14	0·17	1·06	0·14	0·20	0·94	0·19	0·31	0·10	0·18	0·08	0·71
1930 .	0·04	0·06	0·73	0·13	0·15	0·75	0·10	0·23	0·07	0·17	0·24	0·92
1931 .	0·06	0·09	0·94	0·07	0·20	0·67	0·06	0·24	0·04	0·15	0·10	0·75
1932 .	...	...	...	...	...	...	...	...	...	...	...	...
1933 .	0·06	0·17	0·81	0·09	0·13	0·64	0·06	0·30	0·07	0·24	0·18	0·71
1934 .	0·05	0·07	0·83	0·08	0·13	0·75	0·05	0·39	0·03	0·22	0·09	0·79
Average .	0·09	0·22	0·91	0·11	0·23	0·82	0·09	0·25	0·07	0·19	0·15	0·78

APPENDIX X—*concld*

Composition of crops grown in soils of the drain gauges

Percentage potash in crops

Year	Wheat in drain gauge I			Wheat in drain gauge II			Sunn-hemp in drain gauge II		Sunn-hemp in drain dauge IV			
	Straw	Chaff	Grain	Straw	Chaff	Grain	Stalk	Leaves	Slalk	Leaves	Pods	Seeds
1915 .	...	...	0·59	...	...	0·62	1·46	1·35	0·93	0·40	1·72	1·47
1916 .	1·49	0·84	0·59	1·66	0·84	0·45	1·24	1·19	0·86	0·87	1·98	1·40
1917 .	1·55	0·54	0·51	1·56	0·64	0·54	1·20	1·29	1·07	1·01	2·01	1·62
1918 .	1·85	0·74	0·43	2·24	0·82	0·31	1·15	1·35	0·91	1·11	1·87	1·50
1919 .	1·32	0·57	0·35	1·84	0·70	0·43	1·44	1·40	0·66	0·87	1·60	1·27
1920 .	...	...	...	...	...	...	1·13	1·24	0·83	1·08	1·72	1·48
1921 .	1·55	0·85	0·39	1·37	0·83	0·51	1·08	0·85	0·81	1·10	1·59	1·79
1922 .	1·44	0·68	0·42	1·42	0·87	0·57	0·97	0·90	0·74	0·89	1·78	1·47
1923 .	...	...	...	...	...	...	0·97	0·93	0·98	0·68	1·62	1·39
1924 .	1·48	1·30	0·41	1·18	1·31	0·47	1·06	1·09	0·84	0·95	1·24	1·29
1925 .	1·24	1·04	0·45	1·45	1·00	0·49	0·99	1·15	0·66	0·64	1·34	1·39
1926 .	1·33	0·85	0·45	1·44	0·90	0·49	0·90	1·17	0·97	0·65	1·44	1·44
1927 .	1·55	0·79	0·35	1·19	0·87	0·41	0·48	0·87	0·54	0·40	1·83	1·38
1928 .	1·21	0·34	0·35	1·24	0·47	0·34	0·95	1·24	0·43	0·26	1·31	1·33
1929 .	1·24	0·65	0·50	1·42	0·86	0·52	1·10	1·01	0·55	0·65	1·34	1·38
1930 .	1·04	0·56	0·64	1·56	0·87	0·23	1·03	0·98	0·73	0·74	1·37	1·40
1931 .	1·38	0·75	0·42	1·60	1·05	0·32	0·96	1·13	0·65	0·52	1·74	0·86
1932 .	...	...	...	...	...	...	...	...	...	...	...	...
1933 .	2·16	0·51	0·41	1·62	0·75	0·48	1·08	1·19	0·61	0·34	0·83	1·41
1934 .	1·44	0·69	0·41	1·84	1·21	0·57	0·85	1·12	0·39	0·35	1·05	1·24
Average .	1·45	0·73	0·45	1·54	0·87	0·46	1·05	1·13	0·75	0·71	1·55	1·39

SAMPLING OF SUGARCANE FOR CHEMICAL ANALYSES, III

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(Received for publication on 4 September 1942)

The investigation reported in the second paper of this series [Narain and Singh, 1942] was based upon the data obtained from sugarcane grown in single fields under zemindari conditions. However, a greater degree of accuracy could be expected in the figures for different constituents of cane as determined chemically in a varietal, cultural or manurial trial, where a number of replications is usually provided for different treatments. The work described below was therefore conducted with the object of determining the extent of error which attends the sampling of sugarcane from replicated trials and of obtaining an estimate of the differences in the analytical values under these conditions which may be regarded as significant. As the results obtained with five stool samples had shown a high variability, the sampling unit was fixed at 10 stools. With a view to determining the error in sampling, two to four replicated samples each made up of 10 stools were taken from all the plots under any particular variety. Before taking up the detailed investigation, however, preliminary work was undertaken at Lyallpur in 1936-37. For this purpose an experiment in Square 27 was selected in which four varieties, viz. Co 312, Co 285, Co 371 and Co 331 replicated four times were under trial. Four samples of 10 stools each were taken from each one of the 16 plots under this experiment, giving a total of 64 samples. The size of each plot was 1/40th of an acre and the samples were analyzed in the first week of March. These samples were crushed in a three roller bullock-driven mill, and all possible precautions as described by the authors [1938] were taken to ensure maximum extraction. For reasons of economy in space, the figures of the chemical analysis of these samples are not given in this paper. The analyses of variance for different constituents of cane together with those for glucose ratio and purity coefficient are given in Table I.

Table I

Lyallpur (Square 27) 1937

Analysis of variance of percentage juice, sucrose, glucose, total solids, glucose ratio and purity coeffcient

Due to	D.F.	Mean squares								
		Juice	Sucrose		Glucose		Total Solids		Glucose ratio	Purity Coefficient
			On juice	On cane	On juice	On cane	On juice	On cane		
Blocks	3	0·25	0·83	0·27	0·23	0·09	0·96	0·50	9·46	2·37
Varieties	3	62·37	16·33	5·54	0·03	0·01	12·02	2·39	1·53	72·39
Error	9	1·87	0·96	0·39	0·085	0·035	0·79	0·30	3·70	2·90
Between plots	15	13·65	4·01	1·40	0·104	0·043	3·07	0·76	4·42	16·69
Within plots	48	2·489	0·155	0·121	0·011	0·005	0·119	0·118	0·499	0·777
Sampling error per sampling unit		1·578	0·394	0·348	0·105	0·071	0·345	0·344	0·706	0·882
Mean		65·00	16·19	10·52	0·320	0·208	19·16	12·44	2·02	84·45
Coefficient of variation		2·43	2·43	3·31	32·8	34·13	1·80	2·77	35·0	1·044

The last three lines of the table give the sampling errors per sampling unit, the mean values for different constituents and the coefficients of variation for these. In Table II are given similar data for juice and sucrose separately for each variety.

TABLE II

Lyallpur (Square 27) 1937

Analysis of variance of percentage juice and sucrose on juice and on cane of different varieties

Varieties due to	D. F.	Mean squares											
		Co 312			Co 285			Co 371			Co 331		
		Juice	Sucrose		Juice	Sucrose		Juice	Sucrose		Juice	Sucrose	
			On juice	On cane		On juice	On cane		On juice	On cane		On juice	On cane
Between plots .	3	2·573	0·947	0·347	1·497	1·903	0·497	0·198	0·323	0·187	1·593	0·548	0·410
Within plots .	12	4·092	0·288	0·209	3·055	0·093	0·069	1·869	0·103	0·143	0·941	0·136	0·061
Sampling error per sampling unit	...	2·022	0·537	0·457	1·747	0·305	0·263	1·367	0·321	0·378	0·970	0·369	0·247
Mean	...	67·60	14·94	9·38	62·93	15·81	9·96	64·23	16·88	10·85	65·23	17·14	11·18
Coefficient of variation	...	2·99	3·59	4·87	2·78	1·93	2·64	2·13	1·90	3·48	1·49	2·15	2·21

The data presented in Tables I and II lead to a number of conclusions :

1. As far as this experiment is concerned, the effect of block differences was found to be insignificant for all the constituents, thus indicating that the piece of land under this experiment was fairly uniform or soil heterogeneity if found to exist from a consideration of some other factors, e.g. yield, does not exert much influence on the factors discussed.

2. The varieties showed significant differences in juice, total solids and sucrose, as well as in purity coefficient. The differences between the amounts of glucose in different varieties and between glucose ratios are insignificant.

3. The sampling error per sampling unit *per se* was the lowest in the case of glucose and it increased for total solids, sucrose and juice in the order given. However, when these errors are expressed as percentages of the mean values for the various constituents, it was found that glucose showed the highest variation and juice and total solids the lowest.

4. The coefficient of variation for purity coefficient was the lowest of all.

In Table II are given the analyses of variance for juice and sucrose (the latter being expressed both on juice and on cane) separately for each variety. It will be observed from these that the sucrose from Co 285 whether expressed on juice or on cane and from Co 331 when expressed on cane showed significant difference between plots. This indicates that although the block to block differences based upon a pooled estimate of all the varieties in different plots within each block may be insignificant, yet this non-significant difference between blocks may mask the differences between plots under any one variety lying within different blocks, which in comparison with sampling errors may be significant in the case of certain varieties.

In order to obtain detailed information on the above points as well as on the main object of this works, viz. the determination of the extent of error associated with sugarcane samples from replicated trials, a comprehensive investigation was undertaken in the season 1938-39 at different cane growing stations in the Punjab as per details given in the Appendix.

The analyses were carried out thrice in the season and the data obtained examined statistically. The object of analyzing the canes three times in the season, as has been mentioned already in part II [Narain and Singh, 1942] of the series, was to see whether the amount of variation in the results of analysis of a number of samples obtained on different dates decreased with advance in season. There the data were examined separately for each date of analysis but since these showed no appreciable differences in the coefficients of variation pertaining to the three dates of analysis, in this paper a combined statistical examination of the data for the three dates has been done separately for each station.

The investigation was conducted at five different stations and in most cases the different varieties studied were analyzed for juice, total solids, sucrose and glucose. With the exception of Jullundur, the data for sucrose and glucose, from all the other stations have been expressed and examined as percentages on juice as well as on cane. The object of examining the data in this manner was to see if there was any appraciable difference in the accuracy of the results. Since a high correlation

was found to exist between the variability of sucrose and total solids, data for sucrose which is the main constituent of importance in the cane sugar industry have been examined in detail, while those for total solids have been dealt with only in a few cases.

Analytical data

As mentioned already, samples of sugarcane each consisting of 10 stools were obtained on different dates from different varieties grown at various stations and analyzed for juice, total solids, sucrose and glucose. In all 821 individual samples were analyzed. For reasons already given, the original figures of the results of chemical analyses are not presented. It may be mentioned that due attention was paid to the need of finishing in the minimum of time the chemical analysis of all the samples of different varieties which were required to be analyzed at one time at any place. For example, at Karnal the maximum number of samples to be analyzed during a single period was 90 and these were finished in five days. At Lyallpur no less than 30 samples were analyzed per day.

Statistical examination of the data

The chemical data obtained have been examined statistically. As the varieties available at different stations were not the same the results for each station are presented separately.

Gurdaspur

Table III gives the results of the analyses of variance for different constituents of cane combined for all the varieties and for the three dates on which the canes were analyzed. Since it was known that there was a definite correlation between total solids and sucrose, the variance for percentage total solids was calculated only for this station. The six varieties at this station were replicaetd four times and analyzed on three different dates. With three sampling units from each plot, the total number of samples obtained was 216, giving 215 degrees of freedom which have been apportioned as shown in column two of Table III. The values for mean squares corresponding to the various degrees of freedom have been given for each constituent in separate columns. The sampling error per sampling unit, mean value and coefficient of variation for the various constituents are given in the three lines at the bottom of Table III. This method of presentation has been followed for all stations, where a combined analysis of the data has been worked out.

Tables IV and V give the analyses of variance for percentage sucrose expressed on juice and on cane separately for each variety. The object of carrying out a separate analysis for each variety was to obtain an estimate of the extent to which each one of them contributed towards the pooled estimate of variation as given in Table III. It will thus be seen, that analyses for each variety are based upon the results of 36 independent estimations.

Table III

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Pooled analyses of variance of percentage juice, sucrose, glucose and total solids

Due to	D. F.	Mean squares					
		Juice	Sucrose		Glucose		Total solids on cane
			On juice	On cane	On juice	On cane	
Blocks	3	16·82	10·75	4·89	1·92	0·51	2·42
Varieties	5	128·18	33·98	15·76	3·88	1·62	12·85
Error (*a*)	15	4·98	5·57	1·91	0·73	0·24	1·41
Dates	2	85·00	84·42	23·60	7·32	3·74	17·88
V X D	10	3·25	2·14	0·69	0·11	0·04	0·28
Error (*b*)	36	5·36	1·06	0·52	0·11	0·09	0·44
Between plots	71	16·36	7·24	2·74	0·78	0·34	2·07
Within plots	144	0·934	0·497	0·199	0·050	0·032	0·156
Sampling error per sampling unit		0·966	0·705	0·446	0·224	0·179	0·395
Mean		65·26	13·10	8·55	1·30	0·84	10·72
Coefficient of variation		1·48	5·38	5·22	17·23	21·31	3·68

TABLE IV

Gurdaspur

Analyses of variance of percentage sucrose on juice of different varieties

Varieties due to	D. F.	Mean squares					
		Co 312	Co 313	Co 385	Co 421	Co 285	Co 371
Plots	3	14·77	1·35	11·10	3·88	3·81	3·66
Dates	2	13·47	17·92	18·76	1·31	24·40	19·26
P X D	6	1·14	0·57	1·20	0·42	0·31	2·72
Between samples	11	7·10	3·94	7·09	1·53	5·65	5·98
Within samples	24	0·477	0·514	0·706	0·509	0·420	0·356
Sampling errors per sampling unit	..	0·681	0·717	0·840	0·713	0·648	0·597
Mean	..	11·96	14·22	14·21	12·26	13·25	12·69
Coefficient of variation	..	5·69	5·04	5·91	5·82	4·89	4·70

TABLE V

Gurdaspur

Analyses of variances of percentage sucrose on cane of different varieties

Varieties due to	D. F.	Mean squares					
		Co 312	Co 313	Co 385	Co 421	Co 285	Co 371
Plots	3	6·58	0·84	3·86	1·22	1·07	0·85
Dates	2	5·02	4·87	5·96	0·32	4·71	6·17
P X D	6	0·68	0·33	0·32	0·01	0·13	1·11
Between samples	11	3·08	1·29	2·31	0·39	1·22	1·96
Within samples	24	0·199	0·195	0·305	0·335	0·173	0·134
Sampling errors per sampling unit	..	0·446	0·442	0·552	0·579	0·416	0·366
Mean	..	8·07	9·35	9·43	8·11	8·36	7·98
Coefficient of variation	..	5·513	4·73	5·85	7·14	4·98	4·59

TABLE VI

Karnal

Pooled analyses of variances of percentage juice, sucrose, and glucose

Varieties due to	D. F.	Mean squares				
		Juice	Sucrose		Glucose	
			On juice	On cane	On juice	On cane
Blocks	5	28·74	4·02	1·88	0·09	0·04
Varieties	4	382·53	68·86	21·44	0·98	0·40
Error (*a*)	20	5·52	3·65	1·18	0·09	0·04
Dates	2	221·94	171·40	40·59	10·22	4·78
V X D	8	3·02	1·00	0·51	0·12	0·10
Error (*b*)	50	6·16	0·87	0·50	0·04	0·02
Between plots	89	28·76	8·57	3·19	0·33	0·16
Within plots	180	0·749	0·475	0·189	0·014	0·007
Sampling error per sampling unit	..	0·865	0·689	0·435	0·118	0·084
Mean	..	64·04	15·83	10·12	0·48	0·31
Coefficient of variation	..	1·35	4·35	4·30	24·58	27·10

TABLE VII

Karnal

Analyses of variances of percentage sucrose on juice of different varieties

Varieties due to	D. F.	Mean squares				
		Co 312	Co 385	Co 421	Co 285	Co 395
Plots	5	3·72	8·49	3·19	0·85	2·39
Dates	2	37·17	43·08	27·11	24·12	43·92
P X D	10	1·02	1·42	0·77	0·78	0·58
Between samples	17	6·07	8·40	4·58	3·55	6·21
Within samples	36	0·663	0·908	0·242	0·286	0·263
Sampling errors per sampling unit	..	0·814	0·953	0·492	0·535	0·513
Mean	..	14·62	17·11	15·47	15·02	16·92
Coefficient of variation	..	55·7	5·57	3·18	3·56	3·03

TABLE VIII

Karnal

Analysis of variances of percentage sucrose on cane of different varieties

Varieties due to	D. F.	Mean squares				
		Co 312	Co 385	Co 421	Co 285	Co 395
Plots	5	0·90	3·52	0·66	0·12	1·40
Dates	2	10·55	11·84	4·89	4·28	11·04
P X D	10	0·36	0·85	0·68	0·30	0·30
Between samples	17	1·71	2·93	1·17	0·72	1·89
Within samples	36	0·208	0·413	0·122	0·118	0·083
Sampling errors per sampling unit	..	40·56	0·643	0·349	0·344	0·288
Mean	..	9·71	11·41	9·95	9·26	10·29
Coefficient of variation	..	4·70	5·64	3·51	3·72	2·80

Karnal

The results of the statistical examination of the data for all the constituents except total solids, are presented in Tables VI, VII and VIII which have been constructed on lines similar to those followed for Gurdaspur. Here the results of chemical analysis of 270 samples were available for the combined analysis and of 54 samples for each one of the five different varieties.

TABLE IX

Montgomery

Pooled analysis of variance of percentage sucrose on cane

Due to	D. F.	Mean squares				
		Juice	Sucrose		Glucose	
			On juice	On cane	On juice	On cane
Blocks	2	16·87	54·68	18·95	1·488	0·66
Varieties	4	55·01	28·70	10·01	0·863	0·41
Error (*a*)	8	9·09	3·54	1·15	0·048	0·02
Dates	2	603·86	36·76	16·44	0·966	0·48
V X D	8	9·10	1·05	0·81	0·036	0·01
Error (*b*)	20	4·12	1·06	0·45	0·028	0·01
Between plots	44	3·84	8·08	3·08	0·22	0·01
Within plots	90	0·920	0·812	0·330	0·019	0·008
Sampling error per sampling unit	..	0·959	0·901	0·574	0·138	0·089
Mean	..	64·89	13·78	8·93	0·543	0·36
Coefficient of variation	..	1·48	6·54	6·43	25·41	24·72

TABLE X

Montgomery

Analyses of variance of percentage sucrose on juice of different varieties

Varieties due to	D. F.	Mean squares				
		Co 312	Co 421	Co 285	Co 395	Co 371
Plots	2	16 29	11·97	20·31	5·98	4·29
Dates	2	10·29	5·71	5·37	15·28	4·35
P X D	4	2·813	0·368	0·683	5·823	0·673
Between samples	8	8·04	4·60	6·76	8·21	2·49
Within samples	18	1·476	0·709	0·725	0·434	0·713
Sampling errors per sampling unit	..	1·215	0·842	0·851	0·659	0·844
Mean	..	12·18	14·18	13·56	14·97	14·00
Coefficient of variation	..	9·98	5·94	6·28	4·40	6·03

TABLE XI

Montgomery

Analyses of variance of percentage sucrose on cane of different varieties

Varieties due to	D. F.	Mean squares				
		Co 312	Co 421	Co 285	Co 395	Co 371
Plots	2	7·32	4·36	7·11	4·02	0·75
Date	2	3·94	5·34	4·99	5·62	0·31
P X D	4	1·10	0·25	0·57	0·19	0·13
Between samples	8	3·36	2·55	3·18	2·50	0·33
Within samples	18	0·584	0·301	0·331	0·188	0·236
Sampling errors per sampling unit	..	0·764	0·549	0.575	0·434	0·486
Mean	..	8·09	9·42	8·61	9·59	8·92
Coefficient of variation	..	9·44	5·83	6·68	4·53	5·45

Montgomery

The data for this station are presented in Tables IX, X and XI. The total number of samples analyzed was 135 and those for each variety 27.

TABLE XII

Lyallpur Co 285

Analyses of variance of percentage juice, sucrose, glucose and total solids

Due to	D. F.	Mean squares					Total solids on juice
		Juice	Sucrose		Glucose		
			On juice	On cane	On juice	On cane	
Dates	1	126·15	113·71	22·82	0·43	0·192	97·79
Plots	9	2·99	1·36	0·38	0·01	0·002	0·83
D X P	9	0·80	0·62	0·26	0·01	0·003	0·45
Between samples	19	8·43	6·92	1·51	0·03	0·012	5·75
Within samples	40	0·939	0·180	0·091	0·002	0·001	0·160
Sampling error per sampling unit	..	0·969	0·424	0·302	0·045	0·032	0·400
Mean	..	61·11	14·74	9·00	0·26	0·16	18·41
Coefficient of variation	..	1·58	2·88	3·36	17·18	20·00	2·17

TABLE XIII

Lyallpur Co 312

Analyses of variance of percentage juice, sucrose, glucose and total solids

Due to	D. F.	Mean squares					Total solids on juice
		Juice	Sucrose		Glucose		
			On juice	On cane	On juice	On cane	
Dates	1	132·91	111·17	27·20	1·26	0·61	93·75
Plots	9	2·70	1·89	0·92	0·03	0·01	1·51
D X P	9	2·65	0·96	0·31	0·02	0·01	0·52
Between samples	19	9·53	7·20	2·01	0·09	0·04	5·90
Within samples	40	0·561	0·421	0·148	0·006	0·003	0·307
Sampling error per sampling unit	..	0·749	0·649	0·385	0·077	0·055	0·554
Mean	..	65·12	14·11	9·16	0·41	0·27	17·12
Coefficient of variation	..	1·15	4·60	4·20	18·78	20·37	3·22

Lyallpur

At this station the two varieties, viz. Co 285 and Co 312, selected for this investigation were grown in two separate fields; hence the data for the two varieties have been examined separately. Each of the two fields was divided into 10 equal plots and these, with three sampling units and two dates of analyses, gave a total of 60 samples for each one of the two varieties. The results of statistical analyses for these two varieties are presented in Tables XII and XIII.

TABLE XIV

Jullundur

Analyses of variance of percentages juice and sucrose on cane and juice

(Early ripening varieties)

Due to	D. F.	Mean squares		
		Juice	Sucrose	
			On cane	On juice
Blocks	1	5·20	2·38	4·48
Varieties	4	20·22	0·78	1·25
B X V	4	1·14	0·15	0·76
Between plots	9	10·070	0·68	1·39
Within plots	10	0·703	0·105	0·427
Sampling error per sampling unit	..	0·838	0·314	0·653
Mean	..	69·16	7·82	11·24
Coefficient of variation	..	1·21	4·02	5·81

TABLE XV

Jullundur

Analyses of variance of percentages juice and sucrose on cane and juice

(Late ripening varieties)

Due to	D. F.	Mean squares		
		Juice	Sucrose	
			On cane	On juice
Blocks	5	0·68	0·92	2·13
Varieties	4	28·22	5·69	11·28
B X V	20	1·36	0·35	0·72
Between plots	29	8·40	1·18	2·42
Within plots	30	0·864	0·257	0·504
Sampling error per smapling unit	..	0·930	0·507	0·710
Mean	..	69·44	6·20	8·94
Coefficient of variation	..	1·34	8·18	7·94

TABLE XVI

Jullunder

Analyses of variance of percentage sucrose on juice of late ripening varieties

Varieties due to	D. F.	Mean squares				
		Co 285	Co 312	Co 421	Co 432	Co 514
Between plots	5	0·95	1·50	0·96	1·05	0·54
Within plots	6	0·358	1·278	0·363	0·247	0·273
Sampling error per sampling unit	..	0·598	1·130	0·602	0·497	0·522
Mean	..	10·40	7·82	9·05	8·54	8·96
Coefficient of variation	..	5·75	16·57	6·65	5·82	5·83

TABLE XVII

Jullundur

Analyses of variance of percentage sucrose on cane of late ripening varities

Varieties due to	D. F.	Mean squares				
		Co 285	Co 312	Co 421	Co 432	Co 514
Between plots	5	0·43	0·83	0·25	0·66	0·15
Within plots	6	0·170	0·717	0·187	0·102	0·108
Sampling error per sampling unit	..	0·412	0·847	0·432	0·319	0·329
Mean	..	7·26	5·48	6·38	5·72	6·15
Coefficient of variation	..	5·68	15·46	6·77	5·58	5·35

Jullundur

There were two sets of experiments at this station, (*a*) including the early ripening varieties—Co 285, Co 313, Co 332, Co 385 and Co 396, and (*b*) including the late ripening varieties—Co 285, Co 312, Co 421, Co 432 and Co 514. The canes from only two blocks could be examined from the early set as those from the remaining blocks were harvested before the date of analysis. The results of this trial are given in Table XIV. The samples for the five different varieties in the late set were, however, available from six blocks and therefore these with two sampling units gave a total of 60 samples for the combined analysis, and 12 for each variety. The statistical data pertaining to this set are presented in Tables XV, XVI and XVII.

Discussion of results

1. The results of the preliminary experiment carried out at Lyallpur in 1937 had shown that the differences in the composition of the cane from different blocks were insignificant. How far this conclusion was borne out by subsequent experiments will be clear from the observed and expected values of F (ratio of block variance to error variance) given in Table XVIII. For the sake of comparison similar figures calculated for the data pertaining to the previous Lyallpur experiment (Square 27, where the land is known to be particularly uniform) have also been included. It will be seen that both at Gurdaspur and at Karnal the observed F value are smaller than the expected values both in the case of sucrose as well as glucose but not so in the case of juice. This shows that the division of the area into blocks did not prove beneficial in the case of sucrose and glucose. It was however found to be of definite advantage as far as the values of juice are concerned. The observed F values for sucrose and glucose at Montgomery were not only greater than the expected value but were particularly high. As mentioned in the second paper of the series, owing to the presence of alkali salt in patches the land at this farm is not uniform and this seems to be the ikely explanation of these high values. The fact that inspite of these high values, the coefficients of variation are not abnormally high, shows that in this case the division of the land into blocks has been amply justified.

TABLE XVIII

Observed and expected values of F. (ratios of variances due to blocks or plots within blocks and the corresponding error) for juice, sucrose and glucose expressed as percentages on cane from different stations

Station	Observed F values			Expected F values at 5 per cent	System of replication	n_1	n_2
	Juice	Sucrose	Glucose				
Lyallpur (sq. 27) 1936-37	7·48	1·44	2·71	8·84 (Juice and Sucrose) 3·86 (Glucose)	4 randomized blocks of 4 plots each	3	9
Gurdaspur (1938-39)	3·38	2·56	2·13	2·79	4 randomized blocks of 6 plots each	3	51
Karnal (1938-39)	5·21	1·59	1·00	2·35	6 randomized blocks of 5 plots each	5	70
Montgomery (1938-39)	1·86	16·48	33·00	3·34	3 randomized blocks of 5 plots each	2	28
Jullundur (1938-39)	2·00	2·63	..	4·68 (Juice) 2·71 (Sucrose)	6 randomized blocks of 5 plots each	5	20
Lyallpur Co 285 (1938-39)	3·74	1·46	1·50	3·23	1 block of 10 plots	9	9
Lyallpur Co 312 (1938-39)	1·02	2·97	1·00	3·23	1 block of 10 plots	9	9

In the last two lines of Table XVIII, similar data for the two varieties, Co 285 and Co 312 grown at Lyallpur are given. These however relate to differences in plots lying within the two separate blocks each under a different variety. Since in these two cases there was only one variety in one field the question of replication of varieties did not arise. However, as there were 10 plots within the block, the data obtained throw interesting light on the extent of variations in the amounts of different constituents which may be met with at different places within the block which was (10 × 1/40), viz. one quarter of an acre in size. It will be seen from Table XVIII that, except for juice in the case of Co 285, the observed F values are all less than the expected values in the case of both the varieties. This shows that in the case of both varieties the differences in the values of various constituents due to different plots lie within the range of experiemntal errors. It follows from this experiement that both the fields each of which was 1/4th of an acre in size, were fairly uniform and one composite sample of 10 stools picked from any plot within the field will give results which will not differ significantly from those obtained from the entire field.

Considering the F values for the three different constituents of cane analyzed during the season 1938-39, it will be seen that of the 17 cases examined, in five cases the observed F values are significantly greater than the expected F values at five per cent level, showing that in these cases the division of the area into blocks proved to be definitely advantageous. In the remaining cases, with the exception of two, the variances due to soil heterogeneity were greater than the corresponding error variances. The point has been further examined with reference to the figures pertaining to individual varieties analyzed at different stations. Table XIX which gives the observed and expected values of F for sucrose (both expressed on juice and on cane) in the case of these varieties has been constructed from the data given in Tables IV, V, VII, VIII, X, XI, XII, XIII, XVI and XVII. The F values for the four varieties examined at Lyallpur (Square 27) in 1936-37 have also been worked out and included in Table XIX. It will be seen that of a total number of 27 cases examined, the observed F values are greater than the expected values only in 12 cases whether sucrose was expressed on juice or on cane. This indicates that a greater degree of accuracy in the chemical analysis will result if the samples are collected and analyzed separately from each plot under any variety and the figures obtained averaged out. The fact, however, that in the majority of cases, the observed F values are not greater than the expected F values suggests that for rough and routine qualitative work a reasonably accurate estimate of the comparative values of different varieties may be obtained by analyzing one composite sample made by collecting the necessary number of stools from each one of the plots under that variety. It is admitted that this procedure will not satisfy the strict statistical requirements but if a minimum of two such composite samples is obtained it will be a compromise between the statistician and the worker in the field, who is always averse to allowing samples being taken from different experimental

TABLE XIX

Observed and expected values of F. (ratios of variances due to 'between plots' and the corresponding errors) for sucrose (A) expressed on juice and (B) expressed on cane, in the case of different varieties at different stations

Station	Co 312	Co 313	Co 385	Co 421	Co 285	Co 371	Co 395	Co 432	Co 514	Co 331	Value 5 %
(A)											
Lyallpur (Sq. 27) 1936-37	3·29				20·46	3·14				3·99	3·49
Gurdaspur	12·96	2·37	9·25	9·24	12·30	1·35					4·76
Karnal	3·65		5·98	4·14	1·09		4·12				3·33
Montgomery	5·79			32·53	29·73	6·37	1·03				6·93
Jullundur	1·17			2·64	2·65			4·25	1·98		4·39
Lyallpur	1·97				2·19						3·23
(B)											
Lyallpur (Sq. 27) 1936-37	1·66				7·20	1·31				6·72	3·49
Gurdaspur	9·68	2·55	12·06	122·00	8·23	1·31					4·76 & 8·94 for Co 371
Karnal	2·50		4·14	1·03	2·50		4·67				3·33 & 4·68 for Co 421 & 285
Montgomery	6·66			17·44	12·47	5·77	21·16				6·94
Jullundur	1·15			1·32	2·53			6·60	1·36		4·39
Lyallpur	2·97				1·46						3·23

plots a number of time during the growing season. The field worker believes that tampering with the crop during the period of its growth is likely to affect unfavourably the yields which are his main concern. The procedure suggested, however, while keeping within limits the number of chemical analyses which can be carried out on any one occasion, would enable the calculation of the error associated with the results of the analysis of the composite samples. At the time of harvesting, on the other hand, it is desirable to have as accurate an estimate of the composition of the crop as possible, and it is therefore suggested that at that time each plot under treatment be sampled and analyzed separately so as to permit the calculation of detailed statistical data.

2. Considering the coefficient of variation for different constituents of sugarcane (Table XX) it will be observed that as in the preliminary trial, this value is the highest for glucose and lowest for juice.

TABLE XX

Coefficients of variation for different constituents of sugarcane expressed as percentages on juice and cane

Stations	Sucrose		Glucose		Total solids	
	Juice	Cane	Juice	Cane	Juice	Cane
Lyallpur Sq. 27 (1936-37)	2·43	3·31	32·80	34·13	1·80	2·77
Gurdaspur	5·38	5·22	17·23	21·31	..	3·68
Karnal	4·35	4·30	24·58	27·10	..	..
Montgomery	6·54	6·43	25·41	24·72	..	..
Lyallpur (Co 285)	2·88	3·36	17·18	20·00	2·17	..
Lyallpur (Co 312)	4·60	4·20	18·78	20·37	3·22	..
Jullundur (early set)	5·81	4·02	..	..	..	..
Jullundur (late set)	7·94	8·18	..	..	..	..

3. As regards the variations due to varieties it will be seen from the data presented in Tables III, VI, IX, XIV and XV giving the pooled analyses of variance, that the varieties show significant differences as regards juice, total solids, sucrose and glucose. Only in the case of sucrose from the early set at Jullundur (Table XIV) where the number of replications was only two, were the differences non-significant. It will be noticed that in the case of the preliminary trial at Lyallpur the differences between the amounts of glucose in different varieties were insignificant (Table I). In the subsequent trials, however, the differences in the amount of this constituent howsoever expressed, have been found to be significant, the only exception being at Montgomery in which glucose has been expressed on juice. This shows that the method of sampling adopted permits with reasonable accuracy the detection of differences in different varieties.

4. In the second paper of this series it was shown that the coefficients of variation for total solids and sucrose, whether these constituents are expressed as percentages on juice or on cane, remain almost the same. This conclusion, however, was not supported by the results obtained from the 1936-37 trial at Lyallpur (Table I). The work carried out during succeeding years (Table XX) shows that as far as sucrose is concerned the two sets of the figures are almost the same. The figures for glucose which however was not dealt with in paper II, gave in the majority of cases a higher value for the coefficients of variation when expressed on cane than when expressed on juice.

5. The data from these varietal trials have also been examined separately for each one of the varieties at various stations. The coefficients of variation for different constituents of cane expressed both on juice and on cane are given in Tables IV, V, VI, VII, IX, X, XII, XIII, XV and XVI. The data relating to sucrose have been assembled in Table XXI. It will be seen from the figures given in this table that the coefficients of variation for sucrose whether expressed on juice or on cane for any variety at a particular station are of the same order. Amongst the different varieties Co 312 has consistently given figures at all the stations which are greater than the corresponding figures obtained by collective analyses of the data from all the varieties grown at that station. Co 385 which was available at Gurdaspur and Karnal has also given higher values than the pooled estimate of the coefficient of variation for all the varieties at these two stations. All the remaining varieties (except Co 421 at Gurdaspur and Co 285 at Montgomery) gave coefficients of variation which in each case are less than the pooled figure at that station. It may be observed that Co 312 and Co 385 have very little in common with each other, except that they are both soft canes and therefore more sensitive to diseases and to the influence of climate, cultivation factors, etc. It would thus seem that in the case of such canes a higher coefficient of variation may well be expected and if in their case the same degree of accuracy is desired as in the case of other varieties, it will be necessary to increase the size of the sample to more than 10 stools.

TABLE XXI

Coefficients of variation for sucrose in different varieties

Stations	Pooled	Co 312	Co 313	Co 385	Co 421	Co 285	Co 371	Co 395	Co 432	Co 514	Mean
					On juice						
Gurdaspur	5·38	5·69	5·04	5·91	5·82	4·89	4·70	...	...	...	...
Karnal	4·35	5·57	...	5·57	3·18	3·56	...	3·03	...	...	...
Montgomery	...	...	...	...	...	...	...	...	...	...	...
Jullundur	7·94	16·57	...	...	6·65	5·75	...	...	5·82	5·83	...
Mean	5·89	9·28	5·04	5·74	5·22	4·73	4·70	3·03	5·82	5·83	5·49
					On cane						
Gurdaspur	5·22	5·53	4·73	5·84	7·14	4·98	4·59	...	...	...	...
Karnal	4·30	4·70	...	5·64	3·51	3·72	...	2·80	...	...	...
Montgomery	6·43	9·44	...	...	5·83	6·68	5·45	4·53	...	...	...
Jullundur	8·18	15·46	...	...	6·77	5·68	...	...	5·58	5·35	...
Mean	6·03	8·80	4·73	5·74	5·81	5·27	5·02	3·67	5·58	5·35	5·5

6. The effect of dates of analyses (progressive maturity) on the quality of the cane was found to be significant when the canes were analyzed at time intervals shown in the Appendix. No separate table is given to show this significance which, however, can be very easily found in the original tables of analyses variance given in this paper. It is quite clear that the differences due to progressive ripening can be easily detected by adopting the technique of sampling used in these trials.

7. The coefficient of variation of sucrose expressed on juice in the case of Co 318 analyzed at Lyallpur in the season 1935-36 was found to be 1·94 for a 10 stool sample. The average coefficient of variation for sucrose (on cane) for a number of Coimbatore varieties analyzed during the season 1936-37 was 4·78 (Table VI in part II of this series) and in the season 1938-39 it was 5·53 (Table XXI). These two later figures are evidently much higher than the corresponding figure for Co 318. The expectation that in a varietal trial, where a number of replications is provided, this figure would be lower than the figure obtained from single field observations, has not been realized. This, however, may partly be due to seasonal and soil differences. In the two

reasons 1936-37 and 1938-39 there were three common varieties, viz. Co 285, Co 312 and Co 313. The coefficients of variation for sucrose expressed on cane from these variations in these two seasons were as follows :

Variety	1936-37*	1938-39
Co 285	3·65	5·27
Co. 312	5·88	8·80
Co. 313	4·74	4·73
Mean	4·76	6·27

*See Part II of the series

It will be seen that the coefficients of variation for Co 285 and Co 312 are higher in the later season than in the former. Only Co 313 gave similar figures. The fact that in the first season, the average maximum and the minimum figures for any two varieties were 6·03 (Co 390) and 3·19 (Co 223) and in the second season 8·80 (Co 312) and 3·67 (Co 395) (Table XXII), shows that there can be considerable differences in the variability amongst different varieties. The low figures for Co 318 may thus be not only the effect of season but also an inherrent characteristic of this variety,

TABLE XXII

Summary of the results of chemical analysis of different varieties of sugarcane analyzed on different dates at Gurdaspur

Variety	Percentage juice ± 0·668				Percentage sucrose on juice ± 0·297				Percentage glucose on juice ± 0·096			
	D_1	D_2	D_3	Mean ±0·372	D_1	D_2	D_3	Mean ±0·393	D_1	D_2	D_3	Mean ±0·142
Co 312	67·8	68·0	66·7	67·5	10·9	11·9	13·0	12·0	1·96	1·74	1·17	1·62
Co 313	66·3	66·8	63·7	65·6	13·0	14·2	15·5	14·2	1·23	1·00	0·58	0·93
Co 385	66·8	66·9	65·4	66·4	13·1	14·0	15·5	14·2	1·47	1·27	0·80	1·18
Co 421	66·5	66·8	65·1	66·1	11·9	12·3	12·6	12·3	1·95	1·78	1·58	1·77
Co 285	64·0	64·0	60·9	63·0	12·1	12·9	14·8	13·3	1·30	1·23	0·64	1·06
Co 371	63·5	63·1	62·2	62·9	11·3	12·9	13·8	12·7	1·55	1·22	0·97	1·25
Mean	65·8	65·9	64·0	...	12·0	13·0	14·2	...	1·58	1·37	0·95	...
Error	±0·273				± 0·121				± 0·039			

and it is doubtful if we shall be justified in using his as a standard in all cases. The one important conclusion which follows from the above discussion is that for most of the varieties commonly grown in the Punjab, the amount of sucrose as determined by chemical analysis will have a variability of about 5 per cent and for reasons which follow it will not be of much use to attempt to reduce the error by any further increase in the size of the sample. An increase beyond 10 stools, involves a considerable amount of work in picking, handling and crushing the samples, quite incommensurate with the resulting increase in accuracy. Further, in view of the fact that, under the conditions which usually govern the conduct of field trials in the Punjab, it is very seldom that a standard error of less than 10 per cent in the yields from different plots is obtained, it would seem hardly justifiable to attempt by sampling for chemical analysis a reduction in the error for sucrose below 5 per cent. We have seen that the error associated with the estimation of sucrose in juice obtained from a 10 stool sample is 5 per cent, a value which, after allowing a sufficient margin for any increase in error due to unforeseen causes in particular cases, will still be lower than 10 per cent.

8. In the case of replicated trials the errors mentioned in the previous section will become much less, the extent of reduction depending upon the number of replications. This may be illustrated with reference to Gurdaspur. There were six, varieties at this station which were replicated four times and analyzed on three different dates. With three sampling units from each plot the total number of samples obtained was 216. The errors which are applicable to the various comparisons along with the mean values are shown in Table XXII. Of the two errors, (*a*) and (*b*) (Table III) the former is applicable to the mean values of different varieties while the latter is applicable to the effects of dates and the interaction of varieties with dates. Thus the error (*a*) variance for percentage juice is 4·98, which gives the error for the mean values of percentage juice as $\sqrt{\frac{4\cdot99}{36}} = \pm 0\cdot372$. The error for the mean values of different varieties for different dates can be obtained from error (*b*) and will be $\sqrt{\frac{5\cdot36}{12}} = \pm 0\cdot668$, while the error for the mean values of different dates can be obtained by dividing 0·668 by $\sqrt{6}$ and will come to 0·273. The errors for sucrose and glucose obtained at this station have also been worked out on similar lines and are given in Table XXII. Similar data for other stations have been worked out but are not presented here.

It is now easy to locate the significant differences, between varieties, dates, etc. For instance,

Co 312 is a better variety than Co 313 as far as the juice percentage is concerned because the difference of 1·9 between their percentage juice is greater than the critical difference of 1·12, necessary for significance at five per cent level. This conclusion is, however, entirely reversed if we consider the sucrose percentage in these two varieties. The amount of sucrose in Co 313, i.e. 14·2 is greater by 2·21 than in Co 312, the critical difference in this case being 1·18.

A better method of comparing any two varieties, therefore, will be to do so on the basis of, say, the yield of sucrose per acre, for this would automatically take into consideration the amount of juice obtained per acre. Before, however, we illustrate the application of the method of sampling developed in this paper to replicated trials, it is necessary to draw attention to a particular point. In the Punjab, when we express total solids, sucrose, etc. on cane we take into consideration only that amount of these constituents which is present in the juice extracted from a given cane by means of a bullock-driven mill. We take no account of the sugars which are left in the bagasse. This may not be important from the point of view of the zemindar who for the preparation of *gur* has to be content with the amount of juice which can be obtained by using the above mill. From the point of view of the manufacturer of white sugar, however, this would represent a great loss which has to be stopped if his factory is to run economically. In foreign countries formulae have been worked out with the help of which sugar left in the bagasse is taken into account, and this along with that present in the juice gives a better picture of the relative merits of different varieties of sugarcane for the purpose of making white sugar. Till such formulae are worked out we have to be content with the method followed so far. Taking once again the data from Gurdaspur as an example it may now be shown how the statistical method developed in this study may be used in judging the relative merits of the different varieties of cane. For this purpose we take the case of sucrose as determined by chemical analysis in 72 samples obtained on the date of harvesting. The yield of stripped cane from each plot calculated in maunds per acre is given in Table XXIII.

As mentioned already, three samples were obtained from each plot. The percentage sucrose on cane as determined by chemical analysis in the 72 samples from the above 24 plots are given in Table XXIV.

From the figures given in Tables XXIII and XXIV it is possible to calculate the amount of sucrose in maunds per acre obtained from each plot. This has been done and the figures obtained are given in Table XXV. The three values shown against each variety are based upon the chemical analyses of three independent samples obtained from each plot on the date of harvesting.

TABLE XXIII

Yield of stripped cane in maunds per acre at Gurdaspur

Variety	Replications				Mean
	I	II	III	IV	
Co 312 .	524	420	514	334	448·00
Co 313 .	345	307	310	311	318·25
Co 385 .	232	258	280	195	241·25
Co 421 .	467	527	478	395	466·75
Co 285 .	339	394	403	336	368·00
Co 371 .	365	379	424	339	376·75
				Mean	369·83

TABLE XXIV

Sucrose per cent on cane at harvest

Variety	Replications			
	I	II	III	IV
Co 312 . .	7·9	7·5	9·4	10·2
	7·7	7·5	8·6	10·5
	8·5	7·6	9·3	9·7
Co 313 . .	10·1	9·3	10·1	10·9
	8·6	9·9	11·3	9·8
	8·7	9·4	10·5	9·6
Co 385 . .	10·6	10·6	9·0	10·9
	10·1	9·6	9·0	10·7
	10·1	10·7	9·5	10·9
Co 421 . .	7·8	8·5	8·1	8·4
	9·1	8·6	7·9	8·9
	7·8	7·3	7·6	8·4
Co 285 . .	8·6	9·3	9·7	9·0
	8·4	8·8	9·6	9·7
	9·2	7·6	9·1	9·3
Co 371 . .	8·0	8·7	7·8	9·0
	8·8	9·4	7·4	9·7
	8·7	8·7	7·4	9·5

It will be seen from the above that the variance due to blocks is insignificant whereas that due to varieties is significant. The above sampling error compares favourably with the general error (5.55) obtained from all the trials conducted at various stations during this season.

The standard error for this experiment works out to $\sqrt{37 \cdot 26} = 6 \cdot 104$ (or 18·52 per cent) and for varietal means, which are based upon 12 independent observations, it will be $6 \cdot 104/12 = 1 \cdot 762$ (or 5·35 per cent). The critical difference at five

TABLE XXV

Sucrose in maunds per acre

Variety	Replications				Varietal mean
	I	II	III	IV	
Co 312 .	41·4	31·5	48·3	34·1	
	40·3	31·5	44·2	35·1	38·6
	44·5	31·9	47·8	32·4	
Co 313 .	34·8	28·6	31·3	33·9	
	29·7	30·4	35·0	30·5	31·3
	30·0	28·9	32·6	29·9	
Co 385 .	24·6	27·3	25·2	21·3	
	2[illegible]·4	24·8	25·2	20·9	24·3
	23·4	27·6	26·6	21·3	
Co 421 .	36·4	44·8	38·7	33·2	
	42·5	45·3	37·8	35·2	38·2
	36·4	38·5	36·3	33·2	
Co 285 .	29·2	36·6	39·1	30·2	
	28·5	34·7	38·7	32·6	33·2
	31·2	29·9	36·7	31·2	
Co 371 .	29·2	33·0	33·1	30·5	
	32·1	35·6	31·4	32·9	32·2
	31·8	33·0	31·4	32·2	

Statistical examination of the data given in Table XXV gives the following analysis of variance :

Analysis of variance

Source of variation	D.F.	Sum of squares	Mean square	Ratio
Blocks . .	3	221·12	73·71	1·98
Varieties. .	5	1649·84	329·97	8·85
Error . .	15	558·85	37·26	..
Between samples	23	2429·81	105·64	
Within samples	48	152·71	3·18	
Total .	71	2582·52	..	

Sampling errors per sampling unit (10 stools each)
$= 3\cdot18$
$= 1\cdot783$ or $5\cdot5$ per cent

per cent level of significance is 5·3 maunds sucrose per acre. With the help of this figure we are now in a position to judge the relative merits of different varieties which were under trial. It will be seen that both Co 312 and Co 421 are superior to Co 371, Co 313 and Co 385 ; the former being also better than Co 285. The varieties Co 285, Co 371 and Co 313 are all better than Co 385 which has shown itself to be the poorest in this trial, although as far as its sucrose content whether expressed on juice or on cane is concerned, it is one of the best canes.

It will be clear from the above illustration how the relative merits of different varieties or treatments in a replicated trial can be judged with reference to particular factors.

The error discussed above is liable to a small increase due to observations made on samples. In the present case the standard error will increase from $\pm$ 6·104 to $\pm$ 6·359 ($\sqrt{\pm 37\cdot26 + 3\cdot18}$).

SUMMARY

This paper describes the sampling of sugarcane from varietal trials in which a number of replications is provided for each variety. The results of chemical analysis obtained from 885 individual samples collected from different stations have been statistically examined and some important conclusions have been arrived at.

The unit of sampling adopted was 10 stools and generally three such sampling units were obtained from each plot.

It has been found that differences in the composition of the cane from different blocks, are significant only in about 30 per cent of the cases examined. The results from Montgomery show that the division of the area into blocks proved beneficial although this conclusion is not supported so well by the results from Gurdaspur and Karnal. This indicates, as also the results for Co 285 and Co 312 at Lyallpur, that more accurate results could be obtained if samples from all the plots under any variety are analyzed separately and the results averaged or if a composite sample is to be obtained, it must consist of sampling units obtained from each of the plots under that variety.

The above conclusion has also been confirmed by a consideration of the data at all the stations separately for each variety.

At the time of harvesting, however, it is necessary to have as accurate an estimate of the composition of the crop as possible, and it is suggested that at this time each plot under any treatment be sampled and analyzed separately.

As before, glucose has given the highest figure for the coefficient of variation and juice the lowest.

In the case of different varieties a sample consisting of 10 stools of cane has been found to be large enough to permit the detection of differences in their composition as well as those due to progressive ripening. The results from Gurdaspur, taking sucrose as the basis of comparison, have been used to illustrate the method of examining the data.

It has been found that the coefficients of variation for sucrose whether expressed on juice or on cane are of the same order. Glucose, however, in the majority of cases gave a higher value for the coefficient of variation when expressed on juice than when expressed on cane.

In the case of soft canes which are more susceptible to the influence of season and other extraneous factors, higher coefficients of variation are to be expected.

The coefficients of variation for sucrose obtained during the season 1936-37 and 1938-39, viz. 4·78 and 5·55 per cent were much higher than that obtained from Co 318 in 1936 (1·94). It seems that differences in the variability of different varieties are more or less characteristic of the varieties and also depend upon season and locality.

The above variation of 5·55 per cent in sucrose is liable to a reduction, the extent of which will depend upon the number of sampling units obtained from each plot and the number of replications used in the trial.

ACKNOWLEGEMENT

My special thanks are due to Dr Ramji Narain for his helpful criticisms and advice in the preparation of this article.

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APPENDIX

Station	Date of analyses	Number of replications	No. of sampling units of 10 stools each	Varieties analyzed
Gurdaspur	Second week of— (*a*) December 1938 (*b*) January 1939 (*c*) February 1939	4	3	Co 312, Co 313, Co 385, Co 421, Co 285 and Co 371
Karnal	Third week of— (*a*) December 1938 (*b*) January 1939 (*c*) February 1939	6	3	Co 312, Co 385, Co 421, Co 285 and Co 395
Montgomery	First week of— (*a*) December 1938 (*b*) January 1939 (*c*) February 1939	3	3	Co 312, Co 421, Co 285, Co 395, and Co 371
Lyallpur (*i*) (Sq. 27)	First week of March 1937	4	4	Co 312, Co 285, Co 371 and Co 331
Lyallpur (*ii*)	Second week of— (*a*) January 1939 (*b*) March 1939	10	3	Co 312
Lyallpur (*iii*)	Ditto	10	3	Co 285
Jullundur (*i*)	Second week of December 1938	2	2	Early ripening set—Co 285, Co 213, Co 385, Co 332 and Co 396
Jullundur (*ii*)	Second week of January 1939	6	2	Late ripening set—Co 312, Co 285, Co 421, Co 432 and Co 514

The size of the plot in each case was 1/40th of an acre, the breadth and length ratio being about 1 : 5

THE USE OF 8-HYDROXY QUINOLINE AS A MEANS OF BLOCKING ACTIVE IRON AND ALUMINIUM IN THE DETERMINATION OF AVAILABLE PHOSPHORIC ACID OF SOILS BY DILUTE ACID EXTRACTIONS

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(Received for publication on 4 December 1942)

(With one text-figure)

It is generally believed that the best and most convenient laboratory method for the determination of available phosphoric acid of soils is the one involving extraction with dilute acid solutions. The amount of phosphorus extracted from the soil by such a solution is not always an index of the actual solubility of the element or its availability to the crop. The reaction of the soil, the form in which phosphorus is present, the ability of the soil to refix the dissolved phosphorus in the presence of the extracting solution, the nature of the extractant and the procedure of extraction all greatly affect the results obtained. In a recent communication, Weeks and Karraker [1941] compared the usefulness of different solutions in measuring the availability of phosphorus of soils. They extracted the soils with 25 different acid, base and salt solutions under different conditions. These conditions included method of shaking, length of extraction period, fineness of grinding, soil-solution ratio and number of extractions. In this paper attention has been confined mainly to the aspect of refixation of the dissolved phosphorus.

As early as 1916, Russel and Prescott in a study of the solubility of the inorganic soil phosphates in dilute acids pointed out that the amount of phosphate extracted by a dilute acid may not be the whole amount capable of being dissolved from the soil by the particular acid, but is often the resultant between that quantity and the amount again fixed from the solution by the soil. It is obvious that if such a fixation takes place during the acid extraction, the result obtained for the available phosphorus would be an under-estimate of its true value. Again as the soils differ widely in their fixing capacities, they may give different analytical results even when they contain similar quantities of available phosphorus. In order to get a truer understanding of the available phosphorus content of a soil, this reverse reaction should therefore be checked. To eliminate this reverse reaction, Russel and Prescott [1916] suggested a diffusion method in which the phosphorus was removed from the soil as soon as it was dissolved but this method did not find much application in later works.

It is generally believed that phosphorus is fixed in the soil largely through reactions with active calcium, iron or aluminium. Active calcium may be present in soil as an exchangeable base, as calcium carbonate or as any soluble calcium salt. Active iron and aluminium are believed to exist in the soil largely in the forms of the hydrated oxides. Fixation through calcium takes place in the form of precipitation as tricalcium phosphate. This phosphate, though slightly soluble in water, is easily soluble in dilute acids. When iron and aluminium are the active agents of fixation, phosphorus is precipitated as phosphates of iron and aluminium. These latter compounds are only very slightly soluble in acids of strength usually adopted in the determination of available phosphorus of soils. It is thus apparent that the reverse reaction referred to above consists chiefly in the precipitation of the dissolved phosphorus as iron and aluminium phosphates. Any calcium phosphate formed will be redissolved by the extracting acid. The free sesquioxides cannot, however, be removed by a pretreatment without effecting a removal of the available phosphorus as well. If, however, by any means the oxides of iron and aluminium can be deactivated, the reverse reaction can be stopped. In the work to be reported here the use of 8 (OH) quinoline as an agent for chemical deactivation of sesquioxides is considered. The reagent has been tried with $N/2$ acetic acid which is widely used in many countries as an extractant for the determination of available phosphorus of soils.

This reagent is employed as an analytical reagent for precipitating elements such as aluminium, magnesium, iron, etc. It forms compounds in which the hydrogen of the hydroxyl group is replaced to form compounds such as $Al(C_9H_6NO)_3$. Iron and aluminium form such compounds in dilute acetic acid solution (the latter at pH 5) and are precipitated. It was, therefore, thought that if 8 (OH) quinoline is kept dissolved in the extracting acid (in this case $N/2$ acetic acid) the former will precipitate the iron and aluminium oxides while the latter will extract the whole of the soluble phosphorus.

Experimental

To see how far this reagent is effective for the purpose in view, a trial experiment was first made on a synthetic mixture of basic iron phosphate (containing excess of free iron) and mineral phosphate (tricalcium phosphate). The iron phosphate used was almost completely soluble in $N/4$ sodium hydroxide and completely insoluble in $N/2$ acetic acid. The mineral phosphate was completely soluble in $N/2$ acetic acid but insoluble in $N/4$ sodium hydroxide. When the mixture is extracted with $N/2$ acetic acid, the whole of the mineral phosphate should be dissolved in it, if no fixation takes place. As the mixture contains excess of free iron, it is, however, likely that some of the acetic acid soluble phosphorus would be precipitated as iron phosphate. The latter will be extracted along with the iron phosphate of the mixture by a subsequent alkali treatment. If, on the other hand, the acetic acid contains 8 (OH) quinoline and the latter is effective in stopping the fixation, the whole of the mineral phosphate would be extracted by the 8(OH) quinoline-acetic acid. From this point of view, a mixture of 20 mg. basic iron phosphate and 5 mg. mineral phosphate was extracted with $N/2$ acetic acid followed by $N/4$ sodium hydroxide. The experiment was repeated with the same mixture but the acetic acid was replaced by a solution of 8 (OH) quinoline in acetic acid, pH of the solution remaining the same. The latter reagent was prepared by dissolving enough 8 (OH) quinoline in $N/2$ acetic acid to form a 5 per cent solution. This solution was mixed with dilute acetic acid in such a proportion as to make the ultimate solution seminormal. 100 c.c. of this solution was used for extracting the mixture. The results are shown in Table I.

Table I

Blocking of active iron with 8 (OH) quinoline

Solvent— Substance	Acetic acid	8 (OH) quinoline-acetic acid	Sodium hydroxide	Total
1. Mineral P (1·30 mg. P_2O_5).	1·30	..	Nil	1·30
2. Basic $FePO_4$ (2·08 mg. P_2O_5)	Nil	..	1·96	1·96
3. Basic $FePO_4$+Mineral P (2·08+1·3=3·38 mg. P_2O_5)	1·00	..	2·40	3·40
4. Basic $FePO_4$+Mineral P (2·08+1·3=3·38 mg. P_2O_5)	..	1·30	2·04	3·34

It will be seen from Table I that in experiment 3 the whole of the phosphorus of the mineral phosphate did not come in acetic acid. Only 1·0 mg. P_2O_5 was dissolved by it, the remaining 0·3 mg. having been fixed by the iron. This fixed phosphorus was dissolved by the following alkali extraction along with 2·08 mg. P_2O_5 from the iron phosphate, showing that fixation took place in the form of iron phosphate. In experiment 4, 8 (OH) quinoline-acetic acid dissolved all the mineral phosphate showing that no phosphorus was fixed. The subsequent alkali extraction dissolved only the iron phosphate. These experiments domonstrate that 8 (OH) quinoline rendered the free iron of the mixture completely ineffective so far as fixation was concerned. The next step was to see whether this reagent is similarly effective when used in soils.

Effect on fixing power of soils

If 8 (OH) quinoline is able to block the active iron and aluminium of the soil, 8 (OH) quinoline-acetic acid should extract more phosphorus than acetic acid alone. For this study two lateritic soils (A1608 and A3340) containing high amounts of sesquioxides were chosen. A1608 is a laterite from Sierra Leone and A3340 is a typical red arable soil from Middle Lias, near Chipping Morton, Oxford Shire. On examination the acetic acid soluble phosphorus of the two soils was found to be so small that the effect of 8 (OH) quinoline was not quite appreciable. It was therefore decided to determine the fixing power of the soils for added phosphorus from acetic acid and 8 (OH) quinoline-acetic acid solution.

The procedure used was as follows. One gram of soil was shaken for one hour with 200 c.c. of $N/2$ acetic acid containing 0·5 mg. P_2O_5. Another one-gram sample was similarly treated with 8 (OH) quinoline-acetic acid and then the residue with 8 (OH) quinoline-acetic acid containing 0·5 mg. P_2O_5. The first treatment was given to ensure complete reaction of the 8 (OH) quinoline with the sesquioxides. As aluminium is believed to be completely blocked only at pH 5, the latter experiment was repeated using solution adjusted to pH 5 by adding ammonia to the $N/2$ acetic acid solution of 8 (OH) quinoline. Phosphorus in the extracts was in each case determined colorimetrically.* The results are presented in Table II.

It will be seen from Table II that introduction of 8 (OH) quinoline in acetic acid has reduced the fixing power from 90 to 79 per cent of the added phosphorus in soil A1608 and from 58 to 40 per cent in soil A3340. By using solutions adjusted to pH 5, the fixing power was still further reduced to 65 per cent in soil A1608 and 26 per cent in soil A3340. It is evident that this reduction in fixing power of the soils is due to blocking of the

*As the 8 (OH) quinoline-acetic acid extracts of soils were yellow in colour, direct calorimetive determination was not possible. An aliquot of the extract was evaporated to dryness with a few c.c. of a dilute solution of calcium acetate, ignited and phosphorus determined on the ash. If magnesium nitrate is used instead of calcium acetate, a serious loss of the ash takes place owing to its flaring up during ignition.

sesquioxides by 8 (OH) quinoline. Metzger [1940], by removing the free oxides of iron and aluminium, was able to reduce the fixing capacity of 10 soil samples by amounts varying from 20 per cent to 94 per cent. Chandler [1941] showed that extraction of the free iron and aluminium oxides from five clays caused a reduction in the phosphorus adsorptive capacity in practically every case.

TABLE II

Effect of 8-hydroxy quinoline on the fixing power of soils

Soil	Mg P_2O_5 added	Mg P_2O_5 re-covered	Mg P_2O_5 fixed	P_2O_5 fixed as per cent of added P_2O_5
A1608				
$N/2$ acetic acid	0.5	0.049	0.451	90.2
$N/2$ acetic acid +8 (OH) quinoline	0.5	0.106	0.394	78.8
Acetic acid +8 (OH) quinoline at pH 5	0.5	0.173	0.327	65.4
A 3340				
$N/2$ acetic acid	0.5	0.208	0.292	58.4
$N/2$ acetic acid +8(OH) quinoline	0.5	0.300	0.200	40.4
Acetic acid +8 (OH) quinoline at pH 5	0.5	0.371	0.129	25.8

SOLUBILITY OF PHOSPHORUS

A study was next made of the effect of 8 (OH) quinoline in the acetic acid-soluble phosphorus of a number of soils taken from different parts of India. In choosing the soils, attention was given to obtain as wide a range of conditions as possible, especially with respect to their pH and sesquioxide contents. Preliminary experiments showed that maximum amount of phosphorus was dissolved by $N/2$ acetic acid when the soil was shaken with the acid for two hours at a soil-solution ratio of 1 : 250 and the extract filtered immediately after shaking. These conditions were strictly followed in extractions of the soils with acetic acid and 8 (OH) quinoline-acetic acid. The results are presented in Table III and the relation between pH of soils and the increase in acetic acid-soluble phosphorus due to addition of 8 (OH) quinoline is shown graphically in Fig. 1.

A study of the data in Table III and of Fig. 1 reveals that introduction of 8 (OH) quinoline in the acetic acid has caused considerable increases in the easily soluble phosphorus of most of the acid soils. The effect is very marked within a pH range of 4 to 5. In these soils, the soluble phosphorus has been increased from nil to as high as 20 mg. P_2O_5 per 100 gm. of soil. As the pH of the soils increases, the increased solubility due to 8 (OH) quinoline tends to be less and less and ultimately with neutral and alkaline soils, the reagent has practically very little effect on the acetic acid-soluble phosphorus. These findings are in line with the fact that acid soils are usually rich in active sesquioxides and also confirm the view held by many that formation of iron and aluminium phosphates is the predominant form of fixation in acid soils.

TABLE III

Effect of 8-hydroxy quinoline on phosphorate solubility in acetic acid

(Mg P_2O_5 per 100 gm. of soil)

Soil	pH	Acetic acid solution	Acetic acid + 8 (OH) quinoline solution	Increase by 8 (OH) quinoline
Sibsagar, Assam	5.2	8.2	16.0	7.8
Sabour, Bihar	8.3	53.0	56.0	3.0
Coimbatore, Madras	8.4	15.2	17.6	2.4
Kanke, Bihar	5.6	2.2	7.7	5.5
Bogra, Bengal	6.3	22.0	27.0	5.0
Titabari, Assam	4.7	2.9	12.2	9.3
Merida, Bengal	5.7	27.4	36.0	8.6
Rajshahi, Bengal	7.9	53.0	50.0	—3.0
Jessore, Bengal	7.3	116.0	114.0	—2.0
Jalpaiguri, Bengal	5.4	10.0	18.7	8.7
Bankura, Bengal	5.0	Trace	12.5	12.5
Suri, Bengal	5.2	Trace	6.0	6.0
Bidar, Hyderabad	6.4	26.0	30.0	4.0
Telankheri, C. P.	6.3	1.6	6.8	5.2
Buksa Forest, Assam—				
0—9 in.	4.5	3.3	18.5	15.2
9 in—1 ft. 6 in..	4.5	Trace	14.0	14.0
1 ft. 6 in.—2 ft. 3 in.	4.5	Trace	17.5	17.5
Kurseong Forest, Bengal				
0—9 in.	4.5	Trace	20.0	20.0
9 in.—1 ft. 6 in.	4.3	Trace	17.5	17.5
Dacca, Bengal—				
0—6 in.	5.2	1.6	8.4	6.8
6 in.—2 ft. 3 in.	5.3	Trace	6.0	6.0
2 ft. 3 in.—4 ft.	5.2	Trace	8.0	8.0

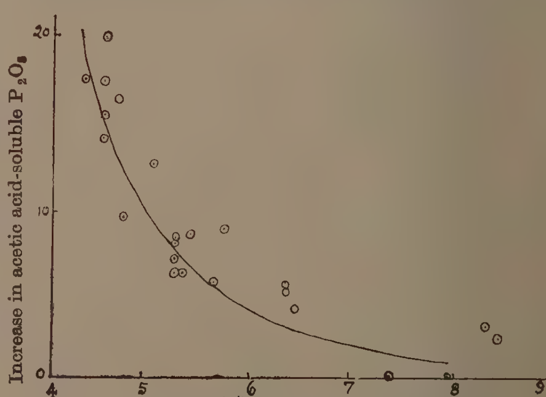

FIG. 1. Relation between pH and increase in acetic acid-soluble P_2O_5 in Mg per 100 gm. of soil by 8(OH) quinoline

As a result of this study, it would seem justified to conclude that 8 (OH) quinoline method will give a better measure of the available phosphorus of soils than the simple acetic acid method. This is specially true for acid soils such as Indian red soils, which contain high quantities of free sesquioxides.

SUMMARY

A study has been made of the use of 8 (OH) quinoline in deactivating free sesquioxides during acid extraction of soils.

The reagent was fully effective in preventing refixation of phosphorus dissolved by acetic acid from a mixture of basic iron phosphate and mineral phosphate.

In two lateritic soils, the phosphorus-fixing capacity was considerably reduced by the use of 8 (OH) quinoline in conjunction with acetic acid.

The 8 (OH) quinoline method has been applied to 22 soils taken from different parts of India. The increased solubility of phosphorus due to 8 (OH) quinoline is very high in acid soils within a pH range of 4 to 5. With the increase in pH of soils, the effect of 8 (OH) quinoline becomes less and less and ultimately in neutral and alkaline soils the effect is practically nil.

It is suggested that 8 (OH) quinoline-acetic acid may be used with more reliance than acetic acid alone in determining the available phosphorus of soils. This is specially true for acid soils containing high quantities of active sesquioxides.

ACKNOWLEDGEMENTS

A part of the work reported here was done in the Rothamsted Experimenal Station, England. Thanks of the author are due to Dr E. M. Crowther and Mr R. G. Warren for their valuable suggestions and criticism.

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RESEARCH NOTE

A SCLEROTIAL DISEASE OF BLACK PEPPER

By S. Chowdhury, Plant Pathological Laboratory, Sylhet, Assam

(Received for publication on 10 December 1942)

Black pepper (*Piper nigrum* L.) is grown to a considerable extent round about Jaintapur and in villages Sakha, Lamin, Sandai and Tamerbil. In January 1943, a serious wilt of the plants was noticed in the plantations in these villages. It was found that 17 to 67·2 per cent of the plants had died of the disease and some of the plantations were almost completely wiped out. A large number of dead and diseased plants were examined and found to have the following characteristics :

The basal part of the plant was found to be discoloured brown or almost black and nearly covered with a white mycelium. A few brown sclerotia were also observed on the surface of the white cobwebby mycelium.

Apart of the stem cut from the basal region was completely washed with corrosive sublimate solution (1 in 1000) for two minutes, rewashed with sterile water and dropped in an oat agar slant. On the third day there was good growth of mycelium and on the fifth day sclerotia were formed. A large number of isolations were made and all gave the same fungus.

In order to see if the fungus was pathogenic, infection experiments were made. Ten black pepper plants were selected and a sclerotium was placed at the ground level near each one of the plants. Next day hyphae from the sclerotium were growing on them. On the succeeding day the mycelium was fairly copious and the stem under it was becoming brown. On the fifth day the surface of the stem for a length of from three to five centimeters from the place of inoculation was brown, soft and rotten and easily broken away at the nodes near the infected place. The white mycelium was running along the stem in straight lines and radiating in a white fan-shaped weft on the surface of the soil. Sclerotia were forming as small white pin-heads on the mycelium, both on the stem and soil. The upper part of the plant showed signs of wilting on the third day and on the fifth day it had collapsed.

The fungus was identified as ***Sclerotium rolfsii*** Sacc.

S. rolfsii Sacc. has not been so far recorded on black pepper in India as Butler and Bisby [1931], Uppal, Patel and Kamat [1935], and Mundkur [1938] do not mention it on this host.

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Butler, E. J. and Bisby, G. R. (1931). The Fungi of India. *Imp. Coun. agric. Res. Sci. Mono.* No. 1

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PLANT QUARANTINE NOTIFICATIONS

NOTICE NO. 2 OF 1943

THE following plant quarantine regulations and import restrictions have been received in the Imperial Council of Agricultural Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi, for loan.

United States Department of Agriculture

1. Cumulative index to service and regulatory announcements Nos. 1 to 149 (inclusive).
2. List of Intercepted Plant Pests, 1942.

Southern Rhodesia

1. Plant Protection Act, 1942.
2. Plant Import Regulations, 1943.

Notification No. F. 15-10/43-A., dated the 9t September 1943 of the Government of India in the Department of Education, Health and Lands.

In exercise of the powers conferred by sub-section (1) of Section 3 of the Destructive Insects and Pests Act, 1914 (II of 1914), the Central Government is pleased to direct that the following further amendment shall be made in the order published with the notification of the Government of India in the Department of Education, Health and Lands, No. F. 320/35-A., dated the 20th July 1936, namely :

To clause 8B of the said order the following proviso shall be added namely :

> "Provided that in the case of tobacco unaccompanied by such certificates, the consignment shall be examined on importation by such officer as the Central Government may appoint on payment of such fee, if any, to meet the cost of such examination, as it may direct."

THE MAYNARD-GANGA RAM PRIZE

APPLICATIONS are invited for the award of the Maynard-Ganga Ram Prize of Rs. 3,000 for a discovery or an invention or a new practical method which tend to increase agricultural production in the Punjab on a paying basis. The prize is open to all, irrespective of caste, creed or nationality and Government servants are also eligible for it. Essays and theses are not accepted. The prize will be awarded for something practically achieved as a result of work done after the prize was founded in 1925. Competitors in their applications must give a clear account of the history of their invention or discovery and must produce clear evidence that it is the result of their own work. In case of an improved crop details of parentage, evolution and history and a botanical description are necessary.

The Managing Committee reserves to itself the right of withholding or postponing the prize if no satisfactory achievement is reported to it, or to reduce the amount of the prize or to divide it if the quality of the entries justify this decision.

Entries should reach the Director of Agriculture, Punjab, Lahore, not later than 31st December 1945.

GIPD—3S—145 IC of AR—10-4-44—600.

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